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Abridged

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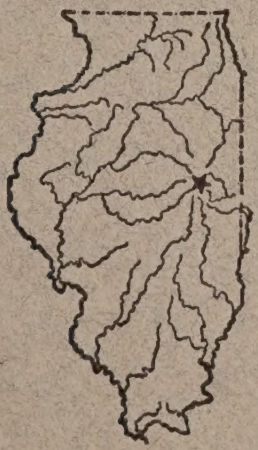
CORN ROOT, STALK, AND EAR ROT DISEASES, AND THEIR CONTROL THRU SEED SELECTION AND BREEDING

IN COOPERATION WITH OFFICE OF CEREAL INVESTIGATIONS
BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

By James R. Holbert, W. L. Burlison,
Benjamin Koehler, C. M. Woodworth,
and George H. Dungan



URBANA, ILLINOIS, MAY, 1925

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FOREWORD

The complete edition of this bulletin, covering two hundred fifty pages, was necessarily limited in number. In response to the urgent call of many Illinois farmers, this abridged edition has been printed. It includes all the colored plates of the original edition and the more important halftones, but the graphs and some of the technical discussion have been omitted and the tables condensed.

The seriousness of the diseases attacking Illinois' great staple crop calls for a generous distribution of any facts that may lead to their control. It is hoped that the information contained in this bulletin will form the foundation for a program that will eventually result in definite improvement in the quality and yield of the corn crop of the state.

The present work is the result of ten years' of combined efforts by representatives of the United States Department of Agriculture, the Illinois Experiment Station, and a few of Illinois' most progressive farmers.

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CORN ROOT, STALK, AND EAR ROT DISEASES, AND THEIR CONTROL THRU SEED SELECTION AND BREEDING

(Abridged Edition)

By James R. Holbert, W. L. Burlison, Benjamin Koehler, C. M. Woodworth, and George H. Dungan[1]

The relation that stalk, ear, and kernel characters of corn bear to yield has been given much attention by plant breeders and agronomists. Recently the relation which the physical characters of the mother plant and seed ear may bear to disease resistance in the progeny has appeared as one of the most important problems of the corn breeder. The breeding and multiplication of productive strains and varieties of corn highly resistant to disease and to injury from unfavorable soil and weather conditions is recognized as a problem demanding the attention and active cooperation of experiment station workers, corn breeders, and corn growers. The present bulletin reports several years of experimental work bearing on various angles of the subject.

LOSSES FROM CORN ROT DISEASES

The actual losses to corn growers thruout the corn-belt states resulting from the use of infected seed and seed especially susceptible to disease and to injuries under unfavorable soil and weather conditions are difficult to estimate accurately. The severity of the losses depends on many factors, among which soil management and soil fertility, crop sequences and crop rotation systems, climatic and seasonal conditions, time of planting, and quality of strain and of seed are most important. The use of infected and inferior seed undoubtedly is responsible for losses varying from 25 to 50 percent on many farms in the corn belt. Occasionally, especially with sweet corn, these diseases have resulted in the loss of almost an entire crop. On adjoining farms, losses frequently vary from less than 5 percent to as much as 50 percent, depending on the character and condition of seed used and the kind of farming

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The authors wish to express their appreciation to Dr. Carleton R. Ball, Dr. H. B. Humphrey, Dr. A. G. Johnson, and Mr. E. D. Funk for encouragement and assistance thruout the investigations reported in this bulletin.

practiced. Parts of fields have commonly been found in which the grain was damaged to the extent of 25 percent by ear rots alone, while in other parts of the same fields grain from good seed was damaged but little.

The extent of disease infection in the seed corn of Illinois again is difficult to estimate accurately. Judging from the many hundred samples that have been sent in for germination tests, as well as from samples secured at many corn shows during the past two years, it is safe to say that the larger part of the seed corn being used thruout

TABLE 1.—COMPARATIVE YIELDS OF CORN FROM GOOD SEED, FROM SCUTELLUM-ROTTED SEED, AND FROM VARIOUS LOTS OF INFECTED SEED

Kind of seed	Number of years covered by experiment	Number of experiments	Acre yield		Reduction in yield following use of diseased seed	
			Good	Diseased		
			bu.	*bu.*	*bu.*	*perct.*
Good	8	57	73.0			
Scutellum-rotted	8	57		60.4	12.6	17.3
Good	5	39	68.4			
Diplodia-infected	5	39		45.0	23.4	34.2
Good	1	5	62.4			
Gibberella-infected	1	5		33.3	29.1	46.6
Good	4	39	68.3			
Fusarium-infected	4	39		62.4	5.9	8.6
Good	3	15	60.0			
Cephalosporium infected	3	15		56.3	3.7	6.2

the state is more or less diseased. Much of it is badly diseased and produces corn very susceptible to infection and easily injured by any unfavorable soil or seasonal condition. A comparatively small portion of it is excellent and produces corn highly resistant to disease. In lots examined by the authors during the past six years the percentage of good seed has ranged from zero to as much as 90 percent, varying with the year, locality, variety, previous selection and breeding, and other factors.

In Table 1 are summarized the data obtained in experiments conducted since 1917 to determine as nearly as possible losses from corn rot diseases following the use of infected or inferior seed.

While any attempt to estimate the combined total losses due to all the diseases under discussion in this bulletin would be extremely hazardous, *on the basis of actual data secured as well as observations made thruout Illinois for a period of years, the authors feel that where inferior and infected seed is used losses to the corn crop from disease, including smut and rust, can very conservatively be placed at 20 percent.*

PART I

CAUSES AND SYMPTOMS OF CORN ROT DISEASES

The corn root, stalk, and ear rot diseases are a group of diseases seriously affecting the corn crop. For brevity, these diseases are sometimes called "corn rot diseases," and frequently simply "corn root rot." It must be realized, however, at the outset that "corn root rot" is not one disease, but several diseases, some of which do not result in any rotting of either roots or stalks. In general, most of these diseases cause a reduction in field stand, a reduction in health and vigor of surviving plants, and a reduction in both yield and quality of grain. They may cause a chlorosis, or yellowing of the leaves, delayed silking and pollination, firing and a general blighting of the plants, lodging, barrenness, and nubbin production in various forms.

Not all the rot diseases of corn can be traced to the same type of causative agent. In general, the corn rot diseases herein described and discussed are due to a combination of causes brought about thru the interrelation of parasitic organisms with unfavorable environment and inferior genetic constitution of the host. Other disorders of the corn plant which are somewhat similar in above-ground symptoms are primarily the result of a lack of proper nutrient elements in the soil, the physiological balance thus being deranged. Some strains of corn, on account of their genetic constitution, have a very narrow range of adaptability and are able to yield satisfactorily only under the most favorable environment, a condition that frequently does not obtain in actual field practice.

This discussion of the causes and symptoms of the corn rot diseases is therefore divided into three parts. First, under *parasitic factors* is given a description of the symptoms of the diseases and a general statement concerning the organisms responsible for them. Second, under *environmental factors* is a discussion of the relation of environment to the development of the diseases. Third, under *genetic factors* is discussed the influence of inherited qualities on resistance and susceptibility of the corn plant to these diseases. There is considerable interaction of causative agencies, however, and any grouping must necessarily be more or less general.

PARASITIC FACTORS CAUSING CORN ROTS

SCUTELLUM ROT

The germination test for corn may be used to determine not only the viability of seed but also the vigor of the seedling and whether the seed is infected with some of the organisms that produce disease.

Under conditions that exist during the germination test, the kernels are subjected to the attack of certain molds, among which *Rhizopus*

spp. is the most common. The degree to which kernels from different ears are able to resist the growth of these molds in the germination test has proved to be a more or less accurate index to the field performance of corn grown from the ears. Corn grown from ears which on the germinator were badly affected with scutellum rot (see description in legends of colored Plate I), a condition usually indicated by invasions with *Rhizopus spp.* on the germinator, has been more susceptible to attacks of soil fungi and to injury from inoculations with certain corn

FIG. 1.—CORN FROM SCUTELLUM-ROTTED SEED (Left) AND FROM GOOD SEED OF THE SAME STRAIN (Right)

An experiment conducted in 1921 on the farm of Mr. Claude Thorpe, De Witt county, the U. S. Department of Agriculture and the Illinois Agricultural Experiment Station cooperating. The outstanding difference between corn grown from seed affected on the germinator with scutellum rot and that grown from good seed is the reduction in early vigor of the plants in the field.

parasites than has corn grown from ears approximately the same in viability and vigor but neither affected with scutellum rot nor infected with parasitic organisms. Under most conditions, corn grown from scutellum-rotted seed has produced less both in total yield and in yield of sound grain than corn grown from good seed.

The fundamental cause of the difference in resistance and susceptibility to *Rhizopus spp.* on the germinator is not known, nor is the disease-susceptibility of corn grown from scutellum-rotted seed fully understood, but this does not alter the economic value of this feature of the germination test in eliminating ears that are likely to produce corn susceptible to disease.

Under the most favorable conditions, scutellum-rotted seed usually produces a satisfactory field stand. If, however, the weather and soil conditions are very unfavorable for germination of corn, the use of such seed may result in a failure. Different lots of scutellum-rotted seed vary greatly in their ability to germinate and yield well under adverse conditions. While occasionally certain lots are only slightly inferior to good seed, in general it may be said that they are distinctly inferior (Table 1) and in certain instances are no better than Diplodia-infected seed under the same adverse conditions.

FIG. 2.—CORN FROM DIPLODIA-INFECTED SEED (Left) AND FROM GOOD SEED OF THE SAME STRAIN (Right), UNIVERSITY SOUTH FARM, URBANA

Seed apparently good but infected with this organism results in a reduced field stand under most conditions.

The most outstanding difference between corn grown from seed affected on the germinator with scutellum rot and that grown from good seed is the reduction in early vigor of the plants in the field (Fig. 1). Early vigor and yield of grain are closely correlated. Plants that are weak or only moderately strong in their early growth are very likely to be late in forming ears and delayed in maturing. If they are decidedly weak in their early growth, they probably will be barren or will produce only nubbins. Thus corn from scutellum-rotted seed usually is inferior to corn from good seed both in total yield and in quality of grain.

DIPLODIA ROOT ROT, EAR ROT, AND SEEDLING BLIGHT

Of the parasitic organisms causing ear rots and seed infections, *Diplodia zeae* (Schw.) Lev. is one of the most important (Table 1). Every year an appreciable amount of the corn crop is damaged by ear rots for which this organism is chiefly responsible. The damage,

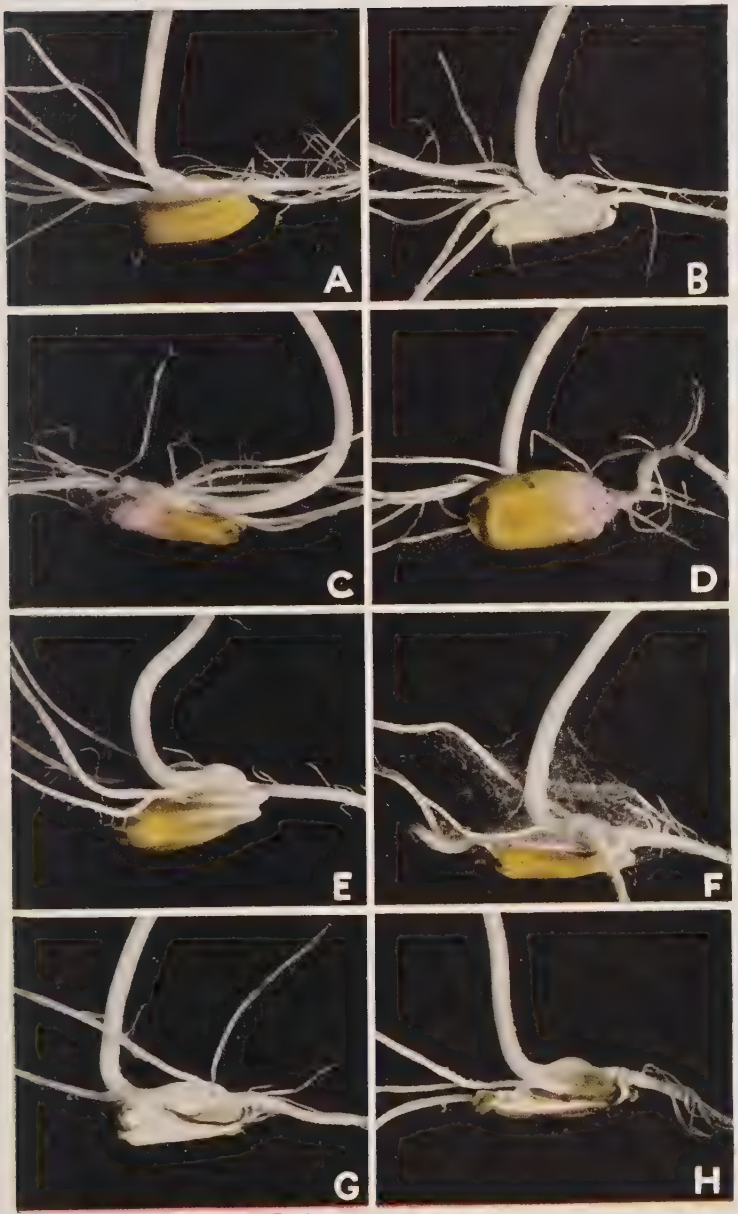
PLATE I

A, B — Vigorous disease-free seedlings.
Note the clean, healthy appearance of both exterior and interior, as well as the large number of strong roots. *The germination test is a valuable means of selecting seed with superior vigor.*

C, D — Fusarium-infected seedlings.
The pink-colored fungous growth on the exterior of the kernels is very characteristic of Fusarium-infected seedlings.

E, G — Scutellum-rotted seedlings with no conspicious mycelial growth on the exterior of the kernels.

F, H — Scutellum-rotted seedlings with Rhizopus growing on the exterior of the kernels.
Note the rotted region (GH) between the endosperm and the embryo portion of the kernel.



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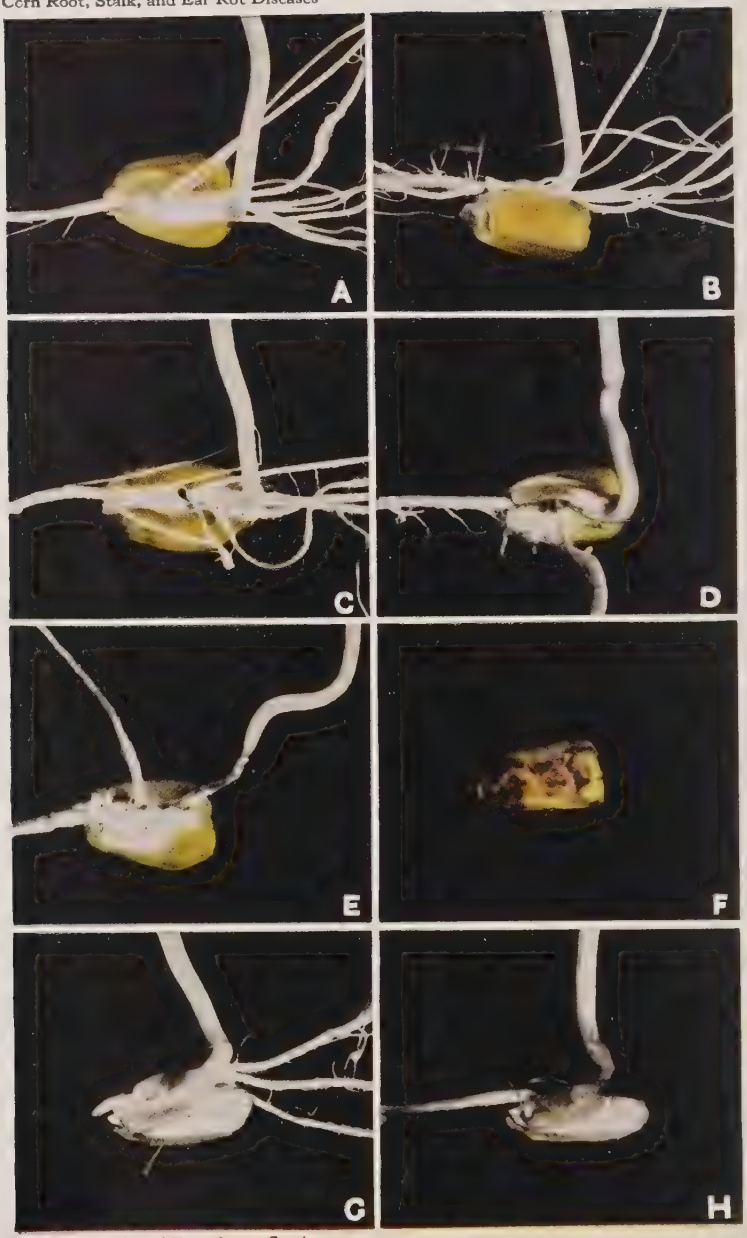

A
B
C
D
E
F
G
H

PLATE II

A, B Vigorous, disease-free seedlings.

C-H Diplodia-infected seedlings and kernel (F).

The germination test is a valuable aid in detecting Diplodia-infected seed.

Diplodia zeae develops abundantly on infected kernels in a germination test and causes decay of the shoots in the region near the kernel. In advanced stages the fungus itself appears as a dense, white mold covering part of the kernel.

however, is not confined to badly rotted ears. The organism may be present in many apparently good ears that are selected for seed purposes. In some lots of seed corn prepared by farmers, 50 percent of the kernels have been found infected chiefly with this disease, while in other lots of seed similarly prepared only a few kernels were infected.

FIG. 3.—REDUCTION IN VIGOR OF CORN FROM DIPLODIA-INFECTED SEED

Above, a hill of corn grown from nearly disease-free seed. Below, two hills of corn grown from Diplodia-infected seed. These were all planted on the same day, two kernels close together in a hill, under uniform soil conditions.

Diplodia develops abundantly on infected kernels in a germination test and causes a decay of the shoots in the region near the kernel (Plate II). In advanced stages the fungus itself appears as a dense, white mold covering part of the kernel. The mycelial growth is seldom conspicuous on rotted roots and shoots except near decayed areas. *Planting of Diplodia-infected seed always has resulted in a reduced stand, many blighted and weak plants, and a lowered vigor and vitality of those plants which survive* (Plate III and Fig. 2). The surviving plants usually make a very irregular growth, depending on the severity

FIG. 4.—CORN FROM GOOD SEED

This corn yielded at the rate of 71 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 5)

FIG. 5.—CORN FROM DIPLODIA-INFECTED SEED

This corn yielded at the rate of 38.1 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington.

PLATE III

A-E Diplodia-infected corn plants.
Note the rotted condition of the mesocotyls and the fewer roots on E as compared with G.

F-G Healthy corn plants.
Note the healthy condition of the mesocotyls and the large number of roots.

The mesocotyls of young corn plants grown from Diplodia-infected seed usually appear dry and brown in contrast to the white, healthy appearance of mesocotyls of plants of the same age grown from good seed.

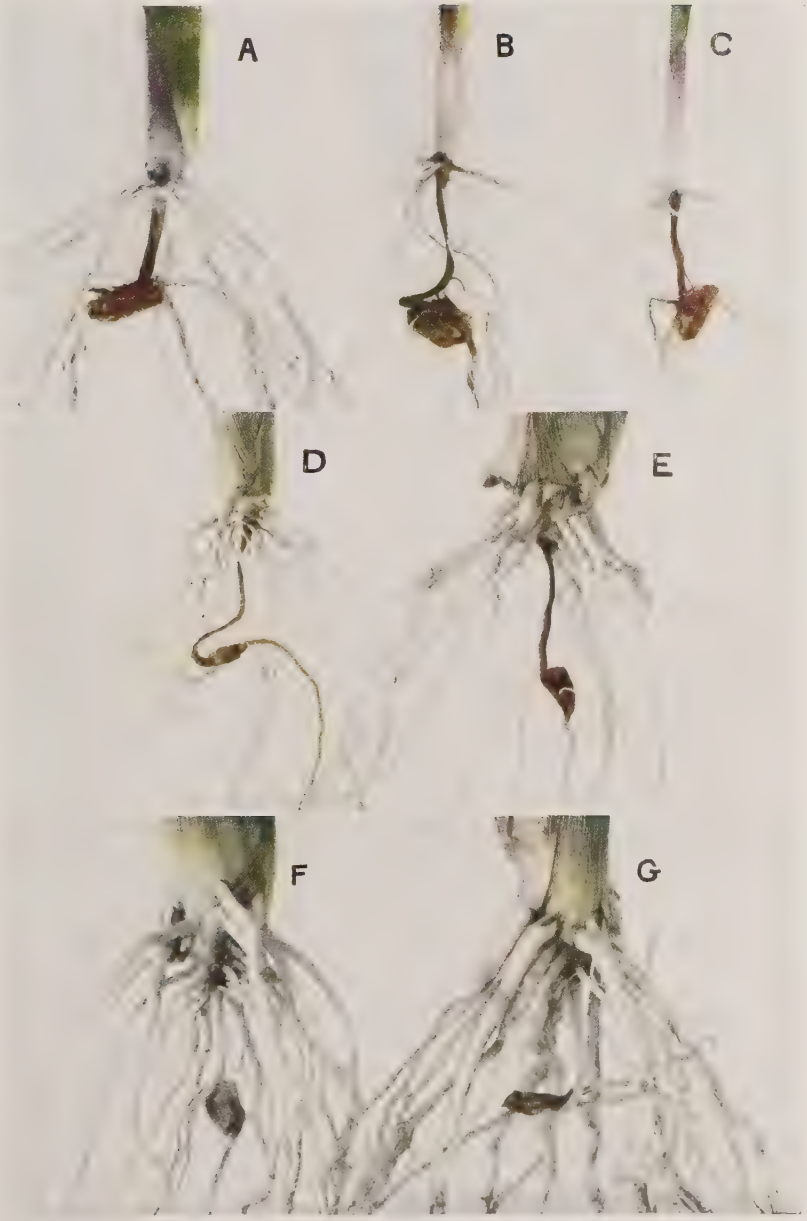

A
B
C
D
E
F
G

FIG. 6.—DIPLODIA-INFECTION AT THE BASE OF THE EAR

FIG. 7.—DIPLODIA-INFECTION AT THE TIP OF THE EAR

Every year there is an appreciable amount of the corn crop damaged by ear rots for which Diplodia is chiefly responsible.

of infection, the resistance of the individual plant attacked, and environmental factors (Figs. 3, 4, and 5). Many weak plants wilt and die as a result of the rotting of the roots near the crown. Other infected plants may neither be blighted nor die, the principal aboveground symptoms in such cases being a marked reduction in vigor and in the height of plants.

The mesocotyls of young corn plants grown from Diplodia-infected seed usually appear dry and brown in contrast to the white, healthy appearance of mesocotyls of plants of the same age grown from good seed (Plate III). There is little evidence that this fungus advances up the stalk from the rotted roots and rotted crown. Frequently more leaning and down stalks occur in corn grown from seed infected with Diplodia than in corn grown from good seed.

In addition to being carried over the winter as dormant mycelium in the seed, *Diplodia zeae* overwinters in diseased corn roots and stalks and diseased shanks and husks, and also in rotted ears left in the field.

Spores of this parasite are picked up by air currents during the summer and fall and may be carried considerable distances. These spores lodge in cavities between the stalk and sheath, on and around the shank, and on the tip of the ear. Under proper temperature and moisture conditions, these spores germinate and frequently infect the

FIG. 8.—CORN FROM GOOD SEED

This corn yielded at the rate of 77.6 bushels per acre. U. S. Department of Agriculture plots on the farm of Mr. Claire Golden, Hillsdale. (Compare with Fig. 9.)

FIG. 9.—CORN FROM SEED INFECTED WITH *G. saubinetii*

This corn yielded at the rate of 38.8 bushels per acre. U. S. Department of Agriculture plots on the farm of Mr. Claire Golden, Hillsdale. (Compare with Fig. 8.)

corn plant thru leaf sheaths, nodes, or ear shanks. Ears may be infected either thru the shank or thru the tip of the ear (Figs. 6 and 7). When the infection occurs soon after the ears form, the infected ears are reduced to a char-like mass by the time uninfected ears are well dented. Frequently, early infection of the young ear shoots results in barrenness.

The germination test is the best means of detecting seed ears infected with this disease.

GIBBERELLA ROOT ROT, EAR ROT, AND SEEDLING BLIGHT OF CORN

Not only does this disease, *Giberella saubinetii* (Mont.) Sacc., cause practically all the wheat scab thruout the corn belt, but it also attacks corn. Koehler, Dickson, and Holbert[1] found that:

"The yield of corn susceptible to root rot was considerably reduced where corn followed badly scabbed wheat in the rotation. *G. saubinetii* was the principal organism isolated from scabbed wheat heads. The same organism when used as inoculum on disease-susceptible corn caused a considerable decrease in stand, general vigor, and yield."

FIG. 10.—A DISEASE-SUSCEPTIBLE STRAIN (Left) AND A HIGHLY RESISTANT STRAIN (Right)

Inbred strains of dent corn growing in contiguous rows, the row on the left in each illustration having been inoculated at planting time with *G. saubinetii*. Note that in the disease-susceptible strain both the stand and the vigor were greatly reduced following inoculation, while the resistant strain apparently suffered no ill effect.

[1] Wheat scab and corn rootrot caused by *Gibberella saubinetii* in relation to crop successions. Jour. Agr. Res. 27, 861-879.

They also found that highly resistant corn did not suffer much reduction in yield when grown after scabbed wheat or when inoculated with a pure culture of the organism.

The spores of *G. saubinetii* on infected wheat heads and old infected corn stalks are carried by air currents, and perhaps are disseminated by a number of other agencies. Many of these wind-blown spores lodge on corn plants, where they find a favorable medium for growth in the moist pollen and dust collected on the ligules at the bases of the leaves, between the sheaths and stalks, and in the cavities surrounding the shanks. Late in the fall and in the following summer perithecia may develop in abundance near the nodes of infected corn stalks. Under some conditions *G. saubinetii* may do damage by producing ear rot.

Rather heavy infection of seed corn with this organism is reported from certain states. While in Illinois such infection has not been general, various lots of seed have been examined which contained from 10 to 15 percent of infected ears. The use of infected seed has resulted in greatly reduced stands and reduced vigor, especially in early plantings (Figs. 8 and 9 and Table 1). It seems evident that in Illinois *G. saubinetii* does considerable damage to corn in the role of a parasitic soil organism causing root rot and seedling blight. There is no evidence that this fungus produces a systemic infection of the plant, but it may do considerable damage to the corn crop by attacking underground parts of the plant. Infected plants frequently are blighted and in severe cases die (Fig. 10).

FUSARIUM ROOT ROT AND EAR ROT

Probably the most common fungus appearing in the germination test of seed corn is *Fusarium moniliforme* Sheldon (Plate I, Figs. C and D). The planting of seed primarily infected with this organism has consistently resulted in a reduced yield of sound corn (Table 1). Where conditions are favorable thruout the growing season, the reductions may be only very slight, but under certain soil conditions Fusarium-infected seed has yielded little more than Diplodia-infected seed. *Seed heavily infected with Fusarium, as revealed in a properly conducted germination test, is inferior for seed purposes. Corn grown from such seed usually is susceptible to serious injury under unfavorable weather and soil conditions.*

As yet field inoculation studies have failed to yield definite data concerning *F. moniliforme* as a root rot parasite of corn. Several strains of this fungus exist, however, and undoubtedly they differ greatly in their ability to parasitize the corn plant. Also, different strains of corn vary widely in their susceptibility to ear rots caused by this fungus. Some strains have been found in which frequently from

FIG. 11.—CORN FROM NEARLY DISEASE-FREE SEED

This yielded at the rate of 66.3 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 12.)

FIG. 12.—CORN FROM FUSARIUM-INFECTED SEED

This yielded at the rate of 60.9 bushels per acre. U. S. Department of Agriculture plots on the farm of Mr. E. D. Funk, Bloomington.

15 to 25 percent of the grain has been damaged; other strains growing in adjacent plots were practically immune.

While corn from seed infected primarily with this organism usually suffers but a slightly reduced stand and only a slight reduction in vigor (Figs. 11 and 12), the yield of sound corn is greatly lowered. Often the differences in yield between corn grown from such infected seed and corn grown from good seed are apparent only after the crop has been harvested and the ears separated into sound and marketable grades and the yields computed on a uniform moisture basis. On soils lacking lime and phosphorus, however, the reduction in total yield frequently has been pronounced. Obviously the roots, stalks, and ears of some strains of corn are very susceptible to rot by this fungus.

Ears conspicuously rotted with Fusarium may be recognized by the characteristic pinkish color of the kernels (Plate I, Figs. C and D, and Plate V). Frequently a number of individual kernels on an ear are badly rotted by Fusarium, while other kernels on the same ear are unaffected. Also, seed ears that apparently are good may be heavily infected with this organism.

BLACK-BUNDLE DISEASE

The black-bundle disease, caused by the fungus *Cephalosporium acremonium* Cord., is widespread in its distribution. Undoubtedly this organism is responsible for much loss to the corn crop, altho the extent of the damage is difficult to estimate accurately at the present time. Losses vary greatly in different sections of the state and from season to season, depending on soil and climatic factors. In certain sections of south-central and southern Illinois, this disease has been known to cause heavy losses, being the principal disease affecting the corn crop in those sections. This was particularly true in 1924. Reddy and Holbert make the following statements concerning this disease.[1]

"Usually symptoms of the black-bundle disease do not become evident during the first half of the growing season. During ear development various symptoms may develop, such as abnormal leaf and stalk colors, barren stalks, nubbin ears, or prolific stalks (Fig. 13). Such stalks usually show blackened fibro-vascular bundles. . . . Often imperfectly developed ears are observed at a number of nodes on a stalk and more frequently multiple-ear production occurs at one node, showing futile attempts at prolificacy. These manifestations—and large succulent stalks should be included—are the readily apparent symptoms associated with the black-bundle disease of corn and can be noted in any commercial field. When plants having any of these symptoms are cut open, blackened vascular bundles nearly always can be found in the nodes and internodes near the base and sometimes thruout the stalk (Fig. 14). Occasionally the fundamental tissue outside the blackened vascular tissues becomes browned or blackened, but usually in only one internode of a stalk.

"Altho purpling, prolific stalks, barren stalks, nubbin ears, and suckering are closely associated with this disease, the blackened fibro-vascular bundles are considered the most distinguishing characteristic, hence, the name Black-Bundle Disease of Corn.

[1] The black-bundle disease of corn. Jour. Agr. Res. 27, 177-205.

FIG. 13.—CORN AFFECTED WITH BLACK-BUNDLE DISEASE

Barren stalks and stalks with multiple ears are extreme types of injury from Cephalosporium infection. The black-bundle disease is responsible for much loss to the corn crop. The plant on the left is apparently healthy.

"However, the number of plants having these symptoms (excluding the black-bundle symptom) represents only a small part of the total number of plants affected by the disease. Plants, including the ears, may appear outwardly healthy yet be infected from the crown to the tassel and every kernel of fine looking ears may bear the organism internally. In these cases the presence of the black vascular bundles within the stalks is the most distinguishing symptom. The ears may be diagnosed by germination in conjunction with microscopic examination.

"Infected ears carry the organism (*Cephalosporium acremonium*) internally in the seed. It develops with the germinating kernel and causes a systemic infection of the plant thru the vascular system. By this means, it invades the ears and eventually the kernels. In this manner it is carried over to the following season.

"Seed infection can be determined macroscopically on limestone-sawdust germinators, . . . but the symptoms are easily overlooked so that up to the present only a fair degree of accuracy has been attained by this method.

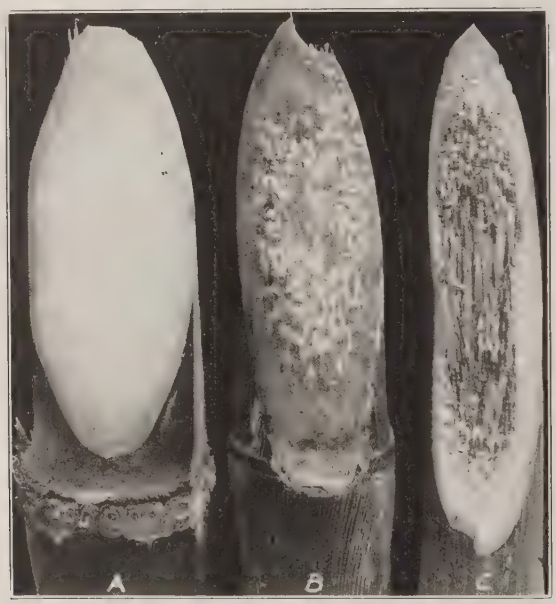


FIG. 14.—THE BLACK-BUNDLE DISEASE

Oblique sections thru corn stalks showing (A) a healthy stalk, (B and C) stalks badly affected with this disease. Losses apparently are much greater where there is a lack of available phosphate or an excess of nitrogen.

"Infected germinating kernels have blanched, white tips, sometimes with noticeable mycelial growth. Often, however, the mycelial growth cannot be seen until examined microscopically. When the symptoms on the germinator are overlooked, the ears often are chosen for seed because germination and the vigor of the infected seedlings are seldom impaired at this time. . . .

"To reduce losses from this disease, it is well to avoid selection of seed ears from stalks having any of this group of symptoms. Probably the best measure of control will come with the development of resistant strains of corn within the varieties."

MISCELLANEOUS EAR ROTS AND MOLDS

When corn is injured by ear worms (*Chloredea obsoleta*) before it is well dented, considerable damage may follow from ear rots caused by fungi other than *Diplodia* and *Fusarium spp.* These include

Aspergillus spp., *Penicilluim spp.*, and other molds. Of these, the black and yellow molds, caused by *Aspergillus niger* and *Aspergillus flavus* Link, respectively, are common.

Where early selected seed is not properly cured and properly stored, a number of molds may grow over the butts of the cobs (Plate IV) and spread over the surface of the ears. In many cases, these fungi may actually penetrate the kernels and seriously affect their seed value. Under moist weather conditions, corn left in the field after heavy killing frosts also may become infected, not only with *Diplodia zeae* and *Fusarium moniliforme*, but with a large number of fungi which under ordinary conditions live only on dead material. The seed value of corn subjected to such unfavorable field or storage conditions is very questionable.

MISCELLANEOUS SOIL-BORNE DISEASES

In addition to the disease-producing organisms already mentioned that may be soil-borne, there are certain other organisms in the soil which may parasitize the corn plant when environmental conditions are favorable. Some of these appear to be of considerable economic importance and their relation to the corn rot diseases is being investigated.

BACTERIAL WILT
(Stewart's Disease)

Bacterial wilt, caused by *Aplanobacter stewarti* (E. F. S.) McCul., is the source of much damage to sweet corn but there is no evidence to date that it causes any material loss in dent corn.

In sweet corn the symptoms are rather distinctive and easily recognized (Fig. 15). The organism causing this disease usually confines its activities to the fibrovascular bundles, in which it multiplies and eventually causes a clogging, thus stopping the transpiration stream. By cutting the stalks of diseased plants obliquely, the yellow affected bundles are seen readily. After the cut surface has been exposed for a few minutes, yellow bacterial ooze exudes in small beads at the cut end of the bundles. If these sticky beads are touched with the finger or a knife blade, they may be drawn out in threads. In older plants the infected bundles sometimes present a dark appearance. Leaves of affected sweet corn plants may or may not turn yellow before wilting, according to the extent of infection and to environmental factors. In some cases plants with well-developed ears may wilt and die within a few days. The disease is seed-borne and apparently does not live over winter in the soil.

On dent corn the symptoms are not so pronounced, and the yellow substance in the infected bundles is not so viscous. However, Reddy has shown that the causal organism from either dent, sweet, or flint corn is equally parasitic on the other two species of corn.

Bacterial organisms other than *A. stewarti* are known to attack the corn plant, but they apparently are not so important as those discussed.

FIG. 15.—BACTERIAL WILT (STEWART'S DISEASE) OF SWEET CORN

The hill at the left shows severe infection. Bacterial wilt is the source of much damage to sweet corn, and also occurs to some extent in dent corn.

CORN SMUT

The common smut of corn caused by *Ustilago zeae* (Beckm.) Ung. is a familiar disease (Fig. 16). At times it has been known to produce heavy losses in Illinois, especially in fields planted with corn very susceptible to smut. During these investigations the authors have observed many instances where plots grown from seed infected with disease-producing organisms were damaged decidedly more by smut than adjacent plots grown from good seed of the same variety. Very frequently strains of corn susceptible to root, stalk, and ear rot dis-

cases have proved very susceptible to injury from smut. Altho smut can be distinguished readily from corn rot diseases and altho it is caused by a widely different organism, it is possible that plants weakened by a corn rot disease may become predisposed, under certain conditions, to injury from smut, and vice versa.

FIG. 16.—CORN SMUT

Altho smut can be distinguished readily from the corn rot diseases and altho it is caused by a widely different organism, it is possible that plants weakened by one of these diseases may become predisposed, under certain conditions, to injury from the other disease.

Common corn smut attacks only above-ground parts of the corn plant. The organism overwinters in soil, manure, and compost. It spreads by means of small spores (sporidia), which are carried by air currents. These spores lodge on the corn plant and usually infect thru stomata and wounds. Mechanical injuries to the plant, therefore, make possible a severe attack of smut, especially on susceptible strains of corn.

Self-fertilized strains of corn vary widely in their resistance and susceptibility to smut. A few have been isolated which are practically immune to this disease. Recombinations of highly resistant or immune strains in first-generation and double crosses appear to offer the most promising method of smut control. However, open-pollinated strains of corn selected by the authors over a period of years from plants not affected with smut have been injured but slightly by this disease.

The recommendation to avoid ears from smutted plants in the selection of seed corn is well founded, and furnishes an effective means for the control of this disease.

CORN RUST

Traces of corn rust caused by *Puccinia sorghi* Schw. can be found in almost every cornfield, but only a few fields have been observed where this disease has resulted in any appreciable damage to the crop. Different strains, as well as individual plants, vary widely in resistance and susceptibility to rust. If seed ears from rusted plants are avoided, it seems unlikely that this disease will ever become economically important under conditions existing in Illinois.

ENVIRONMENTAL FACTORS AFFECTING DEVELOPMENT OF CORN ROT DISEASES

The relation of environment to the development of the corn rot diseases under discussion in this bulletin is very complex.

Altho it is possible, under properly controlled greenhouse conditions, to determine the influence of soil moisture, soil aeration, and certain other environmental factors on the development of the corn rot diseases, yet it must be recognized that such factors seldom, if ever, act independently under actual field conditions. A change in one factor usually is accompanied by changes in other factors, as well as by changes in the biological and chemical conditions of the soil, some of which may profoundly affect the normal metabolism of the corn plant and its resistance and susceptibility to the corn rot diseases. Even a partial understanding of these relationships will require years of careful study, tho much progress has already been made.

SOIL TEMPERATURE AND TIME OF PLANTING

The effect on the corn plant of soil and air temperatures is very marked. When the temperature is too low following planting, the leaves turn yellow and the plants grow very slowly. On the other hand, a very high temperature with an abundance of moisture following planting produces a tall, spindly growth. A rather cool temperature favors root development, while a high temperature favors shoot development. The sturdy growth of the young plant, essential for the best results, is obtained only within a comparatively limited range of temperature, which usually obtains in this latitude during the second or third week in May. Each stage of development in the corn plant is best produced within certain ranges of temperature, a departure from which disturbs the normal activities of the plant and may

favor the attack of certain disease-producing organisms if the particular strain of corn is susceptible to disease.

That the temperature of the soil is "the most important single factor determining the extent of seedling blight" caused by *Gibberella saubinetii*, was found by Dickson.[1] Both his field plantings and his controlled greenhouse experiments showed that Gibberella blighting of corn developed most abundantly in soil temperatures under 66° F.

The effect on yield of early and late planting following inoculation with *Gibberella saubinetii* is shown by the data in Table 2. These data agree with those of Dickson in showing the importance of soil temperature as a factor in damage caused by *G. saubinetii* when seed from strains susceptible to this organism is used.

These experiments were located on soil that was almost ideal from the standpoint of drainage, balanced fertility, and physical condition. In the planting made on May 11, when the mean soil temperature was

TABLE 2.—INFLUENCE OF EARLY AND LATE PLANTING ON FIELD STAND, PERCENTAGE OF VIGOROUS PLANTS, AND YIELD, FOLLOWING INOCULATION OF SEED WITH *Gibberella saubinetii*

Disease-susceptible yellow dent corn planted on virgin prairie sod near Bloomington, 1921; data based on average of 16 plots for each planting

Date of Planting	Field stand		Percentage of strong plants		Acre yield of sound corn			
	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated	Reduction	Odds
	perct.	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	
May 11.....	92.0	78.5	78.8	57.8	56.8	46.6	10.2	>9999:1
May 28.....	92.1	88.6	71.8	68.2	53.5	49.2	4.3	18:1

Meaning of "Odds." In field trials it is common experience to find considerable variation in yields of plots given the same treatment or planted to the same variety, due mainly to variation in soil. For this reason more accurate comparisons are made if the variety or treatment is replicated, for of course the average of several results is much nearer the truth than any single result. By subtracting the average of a number of replications of the same kind of test from that of another, a difference is obtained which may or may not be large enough to be significant, as determined by statistical methods. If, for example, a given variety (A) yields better than another variety (B), is the difference due to the fact that A was grown on better soil than B, or to variety A being inherently a better yielder than B?

The odds give an answer to this question. They indicate what the probability is that A is inherently better than B. The higher the odds, the greater is the probability that there is a real difference between these varieties in yielding power. If the odds are only 4 to 1, we are doubtful; if the odds rise to 30 to 1, our doubt begins to disappear; and if the odds are as high as 9999 to 1 or higher we are practically certain. The odds do not assure us *how much* better A is than B, but only *whether* A is better than B. In other words, by "odds" is meant the degree of probability that the results of an experiment are significant.

[1] Influence of soil temperature and moisture on the development of the seedling blight of wheat and corn caused by *Gibberella saubinetii*. Abs. in Phytopath. 13, 50.

approximately 58° F., the stand was greatly reduced by the inoculation, whereas in the late planting made on May 28, when the mean soil temperature was above 68° F., it was reduced only slightly. Again, in the early planting the percentage of vigorous plants was reduced

TABLE 3.—YIELDS FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED AS AFFECTED BY DATE OF PLANTING

Grown on brown silt loam of high fertility, University South Farm, Urbana, 1920-22

Time of planting	Character of seed	Acre yield		Reduction in sound corn following use of scutellum-rotted seed	
		Total	Sound		
		bu.	*bu.*	*bu.*	*perct.*
Early	Good	80.0	67.3	.....	.....
	Scutellum-rotted	74.8	58.7	8.6	12.8
Moderately early	Good	79.3	66.8	.....	.....
	Scutellum-rotted	71.4	56.8	10.0	15.0
Moderately late	Good	75.3	64.2	.....	.....
	Scutellum-rotted	62.5	46.4	17.8	27.7
Late	Good	73.5	59.6	.....	.....
	Scutellum-rotted	60.6	42.9	16.7	28.0

from 78.8 percent in the uninoculated plots to 57.8 percent in the inoculated. Both total yield and yield of sound corn also were affected by the inoculation, the reduction of 13.0 bushels per acre in total yield

TABLE 4.—YIELDS FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED PLANTED AT VARYING DATES

Average of experiments covering a period of two years, on brown silt loam intermediate in fertility, 1923-24; cool weather conditions accompanying the earliest planting

Date of planting	Acre yield		Reduction in yield following use of scutellum-infected seed	
	Good seed	Scutellum-infected seed		
	bu.	*bu.*	*bu.*	*perct.*
May 2	55.7	31.0	24.7	44.4
May 14	56.6	40.5	16.1	28.5
May 21	56.5	44.9	11.6	20.5
May 31	48.9	31.2	17.7	36.2

and 10.2 bushels in sound corn being very significant in terms of the odds involved. In the late planting there was little reduction in vigor and no significant reduction in either total yield or yield of sound corn.

Altho soil temperature is only one of the many factors involved in different dates of planting, yet it is a very important one. The data in Table 3 indicate that corn grown from scutellum-rotted seed is

INTERMEDIATE PLANTING
Planted with DISEASE FREE Seed
Planted with SCUTELLUM-ROT Seed Lot T.
LATE PLANTING
Planted with DISEASE FREE Seed
Planted with SCUTELLUM-ROT Seed Lot T.

FIG. 17.—EFFECT OF LATE PLANTING ON INJURY FROM SCUTELLUM ROT

U. S. Department of Agriculture experimental plots near Bloomington. Corn grown from scutellum-rotted seed is affected much more adversely by conditions usually accompanying late planting than is corn from good seed.

affected adversely by conditions usually accompanying late planting (Fig. 17), one of the most important factors in late planting being a high soil temperature. On the other hand, when early planting is accompanied by extremely cool weather conditions, corn grown from scutellum-rotted seed again is affected adversely (Table 4), as also is

Planted with DISEASE FREE Seed
Planted with DIPLODIA Infected Seed
INTERMEDIATE PLANTING
Planted with DISEASE FREE Seed
Planted with DIPLODIA Infected Seed
LATE PLANTING
Planted with DISEASE FREE Seed
Planted with DIPLODIA Infected Seed

FIG. 18.—DIPLODIA INJURY AS AFFECTED BY TIME OF PLANTING, EXPERIMENTAL PLOTS, BLOOMINGTON

Seed of strong vitality and free from infection can be planted much earlier than Diplodia-infected seed or seed affected with scutellum rot.

corn grown from Diplodia-infected seed (Table 5 and Fig. 18.) *It is evident that seed of strong vitality and free from infection can be planted much earlier than infected seed or seed affected by scutellum rot. Moreover, the early plantings of good seed have consistently given the highest yields.*

TABLE 5.—YIELDS FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED AS AFFECTED BY DATE OF PLANTING

Average of 16 experiments covering a period of four years, 1921-24

Time of planting	Acre yield		Reduction in yield following use of Diplodia-infected seed	
	Good seed	Diplodia-infected seed		
	bu.	*bu.*	*bu.*	*perct.*
Early	73.9	30.0	43.9	59.4
Intermediate	67.6	41.2	26.4	39.1
Late	63.7	46.2	17.5	27.5

SOIL MOISTURE A HIGHLY IMPORTANT FACTOR

The percentage of moisture in the soil frequently is the most important single factor influencing the behavior of diseased or disease-susceptible corn. Corn plants grown from infected seed or from a strain susceptible to root rot and having partially rotted root systems are the first to suffer from the ill effects of a drouth. On the other hand, strains of corn resistant to root rot, especially resistant strains with extensive and efficient root systems, may not be affected if the drouth does not continue too long. Under such unfavorable conditions of soil moisture as frequently obtain during July and August, differences between healthy and diseased corn may be pronounced and may often result in wide differences in yield of grain at the end of the season.

The percentage of moisture in the soil at planting time and for the first week or ten days following planting may be the most important environing factor in determining the extent of injury in corn grown from Diplodia-infected seed, at least where the soil temperature is comparatively high. In the experiment reported in Table 6 all the corn was planted on the same day, June 2, 1922. On the following day, half the plots were watered uniformly with a hose, and they were kept wet by frequent sprinklings until the twelfth day after planting, when there was a heavy rain. No further attempt was made to control the soil moisture.

Differences in the comparative vigor of the corn grown from good seed and from Diplodia-infected seed on the plots differing in soil moisture are illustrated in Fig. 19. Where good seed was used, there was little difference in total yield of corn from the wet and the dry

plots. In yield of sound corn the difference of 3.8 bushels in favor of the dry plots, with odds of 7 to 1, also is not significant. The corn grown from Diplodia-infected seed, however, showed a reduction of 14.4 bushels per acre in total yield and 14.3 bushels in yield of sound corn, with odds of 640 to 1 and 219 to 1, respectively, on the plots that were kept wet for twelve days following planting.

TABLE 6.—INFLUENCE OF A HIGH AND A MODERATELY LOW PERCENTAGE OF SOIL MOISTURE DURING THE FIRST TEN DAYS FOLLOWING PLANTING, ON THE YIELD OF CORN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn planted June 2, 1922, on brown silt loam of high fertility, Bloomington

Character of seed	Number of plots	Mean acre yields on plots with—		Reduction in yield on plots with high soil moisture	Odds
		Moderately low soil moisture	High soil moisture		
Total yield					
		bu.	*bu.*	*bu.*	
Good	6	88.5	87.8	0.7	1:1
Diplodia-infected	6	70.9	56.5	14.4	640:1
Sound Corn					
Good	6	77.3	73.5	3.8	7:1
Diplodia-infected	6	62.6	48.3	14.3	219:1

In general it may be said that planting at a time of high soil moisture, as compared with moderately low soil moisture, results in greater reductions in yield of sound corn from Diplodia-infected seed than from good seed. This is especially true under moderate to high temperature conditions.

INFLUENCE OF SOIL AERATION

It is a well-established fact that aeration is essential to the productivity of the soil. Lack of aeration, which usually follows imperfect drainage and poor cultivation, results in the accumulation of carbon dioxid and the formation of reductive fermentation. Such conditions usually are injurious to corn plants, particularly if they continue long enough to form a solution of ferrous compounds, which are very toxic and are commonly regarded as one cause of the sterility of badly aerated soils.

Corn grown from infected and disease-susceptible seed is the first to be injured by the unfavorable conditions described above. If the lack of drainage and aeration persist, the resistance of corn grown from good seed also may be broken down.

FIG. 19.—EFFECT OF SOIL MOISTURE ON DIPLODIA INJURY

Corn from good seed (left) and from Diplodia-infected seed (right) on plots differing widely in soil moisture for the first twelve days following planting, near Bloomington. Note the greatly reduced stand and reduced vigor of corn from Diplodia-infected seed on the plots with high soil moisture content. Where good seed was used there was little difference in total yield of corn from the wet and the dry plots.

THE PROBLEM OF SOIL FERTILITY

That it is important to maintain the permanent fertility of the soil is an established fact. A lack of any of the essential plant-food materials is certain to result in a decreased yield. The problems of soil fertility and corn diseases tho closely interrelated constitute two

distinct groups. The soil fertility problem obviously cannot be solved by seed selection and breeding alone, nor can the corn disease problem be controlled entirely by soil treatment and soil management.

Importance of Phosphorus

The importance of the element phosphorus in plant nutrition has received much attention. Thatcher[1] says: "Abundance of available phosphorus early in the plant's life greatly stimulates root growth, and later on it undoubtedly hastens the ripening process; hence this

TABLE 7.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED

Yellow dent corn planted May 14, 1923, on brown silt loam, part of the plots receiving organic manure only and part receiving manure and rock phosphate, North-Central and South-Central rotations, University South Farm, Urbana

Soil treatment	Character of seed	Number of replications	Mean acre yield		Reduction in sound corn following use of Fusarium-infected seed		Odds
			Total	Sound			
			bu.	*bu.*	*bu.*	*perct.*	
Organic manure	Good seed	16	59.1	51.5	.....	.....	
	Fusarium-infected	16	51.5	43.5	8.0	15.5	>9999:1
Organic manure and rock phosphate	Good seed	16	60.1	52.2	.....	.....	
	Fusarium-infected	16	56.1	49.3	2.9	5.6	39:1

element seems to act as the exact antithesis of nitrogen." Large areas of Illinois soils are deficient in phosphates, and the application of phosphates on such soils, together with proper soil management, has been found to result in increased yields of improved quality.

Corn grown from good seed and from infected seed has been found to differ greatly in its response to an increase of available phosphates in the soil, the increase in yield of corn from Fusarium-infected seed being much greater than the increase from good seed. Typical examples of such increases are shown in Table 7. The acre yield of sound corn from Fusarium-infected seed was increased from 43.5 bushels on the plots receiving manure only to 49.3 bushels on the phosphated plots, or 5.8 bushels. The acre yield of sound corn from good seed was increased only .7 bushel by the same treatment. On the plots receiving organic manure only, corn from Fusarium-infected seed yielded 8.0 bushels less than corn from good seed, with odds

[1] Chemistry of plant life. Published by McGraw-Hill Book Co., Inc., New York. 268 pp.

greater than 9999 to 1; while on the plots receiving rock phosphate the difference in yield was only 2.9 bushels, with odds of 39 to 1.

The effects of applications of phosphate on the yields of corn grown from good and from infected seed are not always so pronounced as would seem to be indicated from Table 7, even on soils of the same general type and of apparently equal fertility. The results from forty-two experiments on brown silt loam, conducted at various

TABLE 8.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED SEED

Corn grown on brown silt loam at various points in central Illinois, 1921, 1922

Years represented	Number of counties represented	Number of experiments represented	Character of seed	Acre yield		Increase on phosphated plots	Odds
				No treatment	Phosphated		
			Total Yield				
				bu.	*bu.*	*bu.*	
2 (1921-22)	4	13	Good	59.6	63.9	4.3	62:1
			Scutellum-rotted	51.4	56.0	4.6	65:1
2 (1921-22)	4	10	Good	57.9	61.3	3.4	22:1
			Diplodia-infected	39.7	43.2	3.5	10:1
2 (1921-22)	4	10	Good	58.1	59.4	1.3	4:1
			Fusarium-infected	48.9	54.1	5.2	1427:1
1 (1922)	2	9	Good	63.4	65.0	1.6	3:1
			Starchy	53.8	61.1	7.3	384:1
			Sound Corn				
2 (1921-22)	4	13	Good	50.4	53.9	3.5	18:1
			Scutellum-rotted	41.0	47.6	6.6	69:1
2 (1921-22)	4	10	Good	49.1	53.8	4.7	41:1
			Diplodia-infected	32.6	36.9	4.3	10:1
2 (1921-22)	4	10	Good	50.4	52.6	2.2	10:1
			Fusarium-infected	40.1	47.8	7.7	1110:1
1 (1922)	2	9	Good	52.4	57.7	5.3	3332:1
			Starchy	43.0	49.2	6.2	109:1

points in central Illinois and covering a period of two years, are summarized in Table 8. It will be observed that corn from good seed did not always give a significant increase in yield on the phosphated plots. Obviously the corn from good seed, with its extensive healthy root systems, in many instances was able to get a sufficient supply of phosphates from the soil that received no additional phosphates. In interpreting the responses of healthy corn to applications of phosphate, differences in various strains of corn should be considered. There is evidence that certain strains, on account of their extensive and fibrous

root systems, are more efficient in utilizing limited supplies of this plant-food element than other strains that appear equally healthy.

The ability of corn from good seed to respond favorably to applications of phosphate is further conditioned by date of planting and other important factors which are not within the province of the present bulletin.

Data obtained up to the present time indicate that lack of abundance of available phosphates may be an important predisposing factor with corn grown from Fusarium-infected seed. In the case of corn from good seed in this particular series of experiments (Table 7), neither the total yield nor the yield of sound corn was increased appreciably by applications of phosphate, the increases being only 1.3 and 2.2 bushels per acre, respectively. On the other hand, both total yields and yields of sound corn from Fusarium-infected seed from the same strains of corn were significantly increased, the increases being 5.2 and 7.7 bushels per acre, respectively, with markedly high odds of probability in each case.

Since kernel starchiness indicates susceptibility to the corn rot diseases, as will be developed later in this bulletin, the response of corn from such seed to applications of phosphate is very suggestive (Table 8). The total yield of corn from good seed was increased only 1.6 bushels per acre on the phosphated plots, with odds of only 3 to 1; while the total yield of corn from starchy seed in the same test was increased 7.3 bushels, with odds of 384 to 1.

Potassium Starvation and Disease Susceptibility

The relation of potassium starvation to disease susceptibility has been studied by a number of investigators. Russel,[1] summarizing the results at Rothamsted, England, says: "The vigor and healthiness of the plant are the first to suffer in a bad season, or to succumb to disease."

The effect of applications of potassium sulfate on yields of corn grown from good seed and from diseased seed is shown in Table 9.

The soil on which this experiment was located had not grown a leguminous crop for several years. The supply of decaying organic matter was rather low. Under such conditions a deficiency of available potassium salts might exist. Corn from good seed was not affected either in total yield or in yield of sound corn by applications of potassium sulfate. The quality of the yield from both scutellum-rotted and Fusarium-infected seed, however, was significantly improved, the increases in sound corn amounting to 8.9 and 10.5 bushels

[1] Soil conditions and plant growth. Published by Longmans, Green & Co., London. 1921.

per acre. Corn from Diplodia-infected seed apparently was not benefited in any way by the same applications of potassium sulfate.

In other experiments where the soil was well supplied with decaying organic matter and available phosphates, no such benefits from the addition of potassium salts were observed.

TABLE 9.—INFLUENCE OF POTASSIUM SULFATE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED AND DISEASE-SUSCEPTIBLE SEED

Grown on brown silt loam of medium fertility, Bloomington, 1923

Number of experiments	Character of seed	Acre yield		Increase on potassium sulfate plots	Odds
		No treatment	Treated with potassium sulfate		
		Total Yield			
		bu.	*bu.*	*bu.*	
4	Good	67.0	68.0	1.0	3:1
4	Scutellum-rotted	62.0	66.2	4.2	9:1
4	Diplodia-infected	51.4	48.7	−2.7	5:1
4	Fusarium-infected	64.1	66.9	2.8	3:1
		Sound Corn			
4	Good	46.2	46.6	0.4	1:1
4	Scutellum-rotted	30.2	39.1	8.9	141:1
4	Diplodia-infected	31.5	34.2	2.7	11:1
4	Fusarium-infected	38.9	49.4	10.5	66:1

INJURIOUS CONSTITUENTS IN SOIL SOLUTION

Toxic Substances

The problem of organic and inorganic constituents in the soil which are injurious to plants has received much attention, both in the United States and in other countries. The evidence seems fairly conclusive that toxic substances may form in poorly drained and poorly aerated soils and in soils lacking calcium carbonate, or lime. The toxic properties of "acid" or "sour" soils may result either from the presence of true acids in the soil or from a lack of materials that are capable of acting as a base for certain desirable chemical reactions. In the latter case the presence of soluble aluminum and ferrous salts, and in certain instances manganese, are believed to be largely responsible for the toxic effect of such soils upon plant growth.

Soluble aluminum compounds do not form readily in soils well supplied with lime and available phosphates. Moreover, applications of limestone in proper amounts change these soluble compounds into insoluble and non-acid forms. Conner[1] and others expressed the belief that the beneficial effects of applications of available phosphates

[1] Liming in its relation to injurious inorganic compounds in the soil. Jour. Amer. Soc. Agron. 13, 113-124.

are due as much to their rendering the aluminum salts insoluble as to the extra supply of available phosphate they furnish.

Hoffer and Carr[1] found that root rots of corn were more severe "in soils notable for their deficiencies in lime and available phosphates than in other soils," and showed that the absorption and ac-

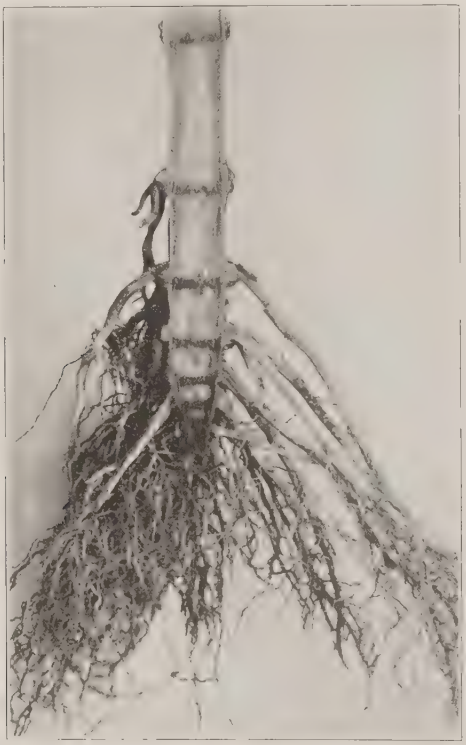


FIG. 20.—FERROUS IRON POISONING
Note the badly discolored nodes.

cumulation of iron and aluminum salts in the nodal tissues resulted in a purplish brown discoloration followed by a disintegration of the affected tissues (Fig. 20). The accumulation of these metallic salts also resulted in a clogging of large numbers of the vascular bundles. In a later publication Hoffer and Trost[2] made the following statement:

"The accumulation of iron and aluminum compounds in the nodal tissues of corn plants is affected by conditions in the soil as well as by the genetical composi-

[1] Accumulation of aluminum and iron compounds in corn plants and its probable relation to root rots. Jour. Agr. Res. 23, 801-823.

[2] The accumulation of iron and aluminum compounds in corn plants and its probable relation to root rots. II. Jour. Amer. Soc. Agron. 15, 323-331.

tion of the strain of corn. The accumulations of aluminum in the plants are associated with retarded growths and increased susceptibility of certain strains to root rots. . . . When iron compounds gradually accumulate in the nodal tissues of the plants, the growth of the stalks may be little affected, but the disintegrations of the nodal tissues are accompanied by increased susceptibilities of the plants to root rot."

The reaction of the soil solution, in addition to being an important factor in determining the availability of phosphates and other essential plant-food materials, has a pronounced influence on the behavior of parasitic soil fungi.

TABLE 10.—INFLUENCE OF LIMESTONE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED AND DISEASE-SUSCEPTIBLE SEED

Corn grown on brown silt loam at various points in central Illinois, 1919 to 1922

Number of years represented	Number of counties represented	Number of experiments represented	Character of seed	Mean acre yield		Increase in yield on limed plots	Odds
				No treatment	Limed		
				bu.	*bu.*	*bu.*	
4 (1919-22)	7	17	Good.....	67.9	70.1	2.2	5:1
			Scutellum-rotted.....	57.4	62.0	4.6	191:1
3 (1920-22)	6	12	Good.....	78.2	79.1	0.9	4:1
			Diplodia-infected...	53.9	57.7	3.8	6:1
2 (1921-22)	6	6	Good.....	64.9	66.6	1.7	1:1
			Fusarium-infected...	57.3	61.0	3.7	14:1
1 (1922)	3	6	Good.....	75.6	77.1	1.5	7:1
			Starchy.....	68.4	69.5	1.1	3:1

Limestone as a Corrective for Toxicity

Summarized data of all the experiments on the relation of liming to certain of these diseases are reported in Table 10.

These experiments were located on fields representative of large areas of brown silt loam in central Illinois. At no place did the corn grown from good seed show any significant increase in yield on the limed plots. Of the diseased seed, only that affected with scutellum rot showed a significant increase as a result of liming, the increase being 4.6 bushels per acre, with odds of 191 to 1, as contrasted with an increase of 2.2 bushels from good seed, with odds of 5 to 1.

CROP SEQUENCE AND CROP ROTATION AS IMPORTANT AS SOIL TREATMENT

Previous cropping, or crop sequence, is one of the most important environing factors determining the extent of injury caused by corn rot diseases.

In the experiments reported in Table 11 the comparisons were made in the same or adjacent fields of the same soil type and as nearly alike in all other factors as possible. In no case was there a

FIG. 21.—INFLUENCE OF CROP SEQUENCE ON INJURY FROM SCUTELLUM ROT

The reduction in yield of sound corn from scutellum-rotted seed (right) as compared with the yield from good seed (left) was very much greater in the field where corn followed soybeans in a rotation of corn, corn, corn, soybeans (below) than where it was the third year of corn in the same rotation (above) (Table 12). Of the environing factors affecting the development of the different corn rot diseases, the problem of crop rotation and crop sequence takes a place second to no other under conditions existing at the present time in central Illinois.

TABLE 11.—INFLUENCE OF CROP SEQUENCE ON YIELD FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED

Yellow dent corn grown at various points in Illinois, 1920 to 1922

Experiment No.	Year	Location (Illinois)	Crop sequence	Seed lot No.	Character of seed	Acre yield		Reduction in sound corn following use of scutellum-rotted seed	
						Total	Sound		
						bu.	*bu.*	*bu.*	*perct.*
1	1920	Bloomington	Wheat, clover, clover	1	Good	88.7	85.0		
				2	Scutellum-rotted	76.5	70.9	14.1	16.6
			Wheat, corn, spring wheat (scabbed)	1	Good	81.8	75.4		
				2	Scutellum-rotted	57.9	42.3	33.1	43.9
2	1921	Bloomington	Virgin prairie sod	3	Good	94.3	72.3		
				4	Scutellum-rotted	89.5	60.5	11.8	16.3
			Corn, oats, wheat	3	Good	87.0	63.7		
				4	Scutellum-rotted	67.9	32.4	31.3	49.1
3	1921	Peoria	Oats, wheat, clover	5	Good	74.6	56.7		
				6	Scutellum-rotted	72.2	51.6	5.1	9.0
			Corn, corn, corn	5	Good	81.7	65.8		
				6	Scutellum-rotted	68.3	53.1	12.7	19.3
4	1922	Cambridge	Oats, corn, oats	7	Good	66.4	62.2		
				8	Scutellum-rotted	63.9	59.9	2.3	3.7
			Corn, corn, corn	7	Good	66.0	62.3		
				8	Scutellum-rotted	59.2	55.1	7.2	11.6

FIG. 22.—INFLUENCE OF CROP ROTATION ON INJURY FROM SCUTELLUM ROT

Rows on the left are from scutellum-rotted seed; those on the right are from good seed. Above, first year corn after a legume in a rotation of soybeans, corn, corn, corn. Below, first year corn after a legume in a rotation of clover, corn, corn, wheat. Soil treatments have been the same in each rotation and the date of planting was the same. University South Farm, Urbana.

Corn from good seed responded better to more favorable conditions in crop rotations than did corn from scutellum-rotted seed. Data from these rotations up to the present time indicate that crop rotation is as important a factor in determining yield of corn as are soil treatments.

TABLE 12.—SUMMARY OF THREE YEARS' DATA SHOWING YIELDS FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED IN THREE STANDARD CROP ROTATIONS[1]

Yellow dent corn grown on the University South Farm, Urbana, 1920 to 1922

Name of rotation	Crop sequence	Years since legume	Character of seed	Acre yield		Reduction in sound corn following use of scutellum-rotted seed	
				Total	Sound		
				bu.	*bu.*	*bu.*	*perct.*
Northwest	Potatoes, corn, soybeans, alfalfa	2	Good	76.1	63.6	.....	.....
			Scutellum-rotted	65.9	49.9	13.7	21.5
North-Central	Corn, corn, spring grains, clover	1	Good	71.3	64.6	.....	.....
			Scutellum-rotted	60.3	51.5	13.1	20.3
		2	Good	65.6	56.9	.....	.....
			Scutellum-rotted	57.6	47.9	9.0	15.8
South-Central	Corn, corn, corn, soybeans	1	Good	53.8	47.0	.....	.....
			Scutellum-rotted	46.9	39.9	7.1	15.1
		2	Good	46.9	40.9	.....	.....
			Scutellum-rotted	42.7	35.4	5.5	13.4
		3	Good	40.0	30.0	.....	.....
			Scutellum-rotted	34.1	27.3	2.7	9.0

[1] The North-Central and South-Central rotations have had the same soil treatments in every respect. The Northwest rotation, however, has received more rock phosphate and, in addition, heavy applications of manure.

difference of more than one day in date of planting. Where corn followed corn or wheat, the reduction in acre yield from scutellum-rotted seed was significantly greater in every instance than where corn followed a legume, prairie sod, or oats. In the experiment at Bloomington in 1920 there was a difference of 14.1 bushels in acre yield between corn from good seed and from scutellum-rotted seed where corn followed clover, but in the same field where corn followed badly scabbed spring wheat the difference was 33.1 bushels. Results in 1921 were very similar; there was a reduction of 11.8 bushels in acre yield of sound corn on the virgin soil field, but a reduction of 31.3 bushels just across the fence on soil that had been in grain crops the preceding years. At Peoria, in 1921, the difference in the yield of corn from good seed and from scutellum-rotted seed was 5.1 bushels per acre where corn followed clover and 12.7 bushels where corn followed corn. Results at Cambridge the following year were similar.

Since 1920, plantings of good seed and various lots of diseased seed have been made in three long-time rotations on the University South Farm, Urbana. A summary of three years' field data from good seed and from scutellum-rotted seed is presented in Table 12. In the Northwest rotation the acre yields of sound corn averaged 63.6 bushels and 49.9 bushels, respectively, showing a reduction of 13.7 bushels due to scutellum-rotted seed. Soil treatments on the North-Central and South-Central rotations have been the same since the rotations were started in 1907. They have consisted of an application of rock phosphate at the rate of 2,000 pounds per acre every four years.

Data from these rotations up to the present time indicate that crop rotation is as important a factor in determining yield of corn as are soil treatments (Fig. 22). Corn from good seed responded better to the more favorable conditions in each rotation than did corn from scutellum-rotted seed. Of the environing factors affecting the development of the different corn rot diseases under discussion in this bulletin, the problem of *crop rotations* and *crop sequence* takes a place second to no other under conditions existing at the present time in central Illinois.

GENETIC FACTORS, OR INHERITANCE, AND SUSCEPTIBILITY TO DISEASE

From the data and discussion presented up to this point it is evident: (1) that pathogenic bacteria and fungi are capable of causing diseases of great economic importance to the corn crop under conditions usually existing in the corn belt; and (2) that such environing factors as soil temperature, soil moisture, soil aeration, available plant food materials, soil toxicity, and crop sequence exercise a strong influence on the development and expression of disease.

However, the extent to which the corn plant is affected by either parasitic or environing factors depends largely on the inherent qualities, or genetic composition, of the particular corn plant in question.

FIG. 23.—HERITABLE DIFFERENCES IN EXTENT AND CHARACTER OF ROOT SYSTEMS

Representative root systems of two inbred strains of dent corn. The one illustrated above is susceptible to leaf firing; the lower one is highly resistant to both leaf firing and root rot. Note difference in character and extent of the two root systems.

Certain strains of corn, on account of their superior inherent qualities, are able to develop and function normally under a wide range of environmental conditions, while other strains vary greatly in their susceptibility to injury when grown in association with the same en-

vironmental and parasitic factors. Differences in genetic factors seem to be the only logical explanation for these variations.

The relation of all these known factors to disease resistance and productiveness of seed corn has not been determined, but it is common observation that corn containing many weak and undesirable characters is not likely to yield satisfactorily. In addition to the heritable

FIG. 24.—SUSCEPTIBILITY (Left) AND RESISTANCE (Right) TO INJURY FROM DROUTH

Certain strains, apparently independent of any parasitic factors, have such a limited and inefficient root system that they are unable to function normally during the hot days of July and August under conditions of low soil moisture.

characters already known there undoubtedly are many other characters which are very important in determining the behavior of a strain of corn and its ability to resist disease and injury from unfavorable environment. Certain strains, apparently independently of any parasitic factors, have such a limited and inefficient root system (Fig. 23) that they are unable to function normally during the hot days of July and August, when the soil moisture is low (Fig. 24). Other strains not only have fewer roots and a higher ratio of tops to roots, but are very susceptible to a rotting of the roots and to injury

from inoculation with disease-producing organisms (Fig. 25). On the other hand, strains of corn with the same total number of main roots may differ greatly in their resistance to root rot (Fig. 26).

In general it has been found that weak-rooted strains, when compared with better-rooted strains, are more likely to lodge and are

FIG. 25.—HERITABLE DIFFERENCES IN RATIO OF ROOTS TO TOPS

Representative plants of two self-fertilized strains, illustrating the significant differences in the character and extent of root systems that exist between strains which may have an apparently equal growth above ground. These differences in root systems are reflected in the response of these strains to disease and to unfavorable soil and weather conditions.

lower in grain production (Fig. 27), owing in part to being more susceptible to injury from unfavorable environment and in part to parasitic factors, as is shown by data presented in Table 12. The final field stands of strong-rooted and weak-rooted strains in the uninoculated plots were practically the same, 90.2 and 90.0 percent, respectively. The mean yield of the strong-rooted strains was 64.5 bushels per acre, while that of the weak-rooted was 38.8 bushels. Inoculation with *Gibberella saubinetii* reduced the mean yield of the strong-rooted strains 4.7 bushels per acre, while it reduced the mean yield of the weak-rooted strains to 10.4 bushels. In the former case the odds were 81 to 1; in the latter they were more than 9999 to 1.

Altho variations in disease resistance are greater in open-pollinated corn than in uniform inbred strains, *yet there are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection.* Table 14

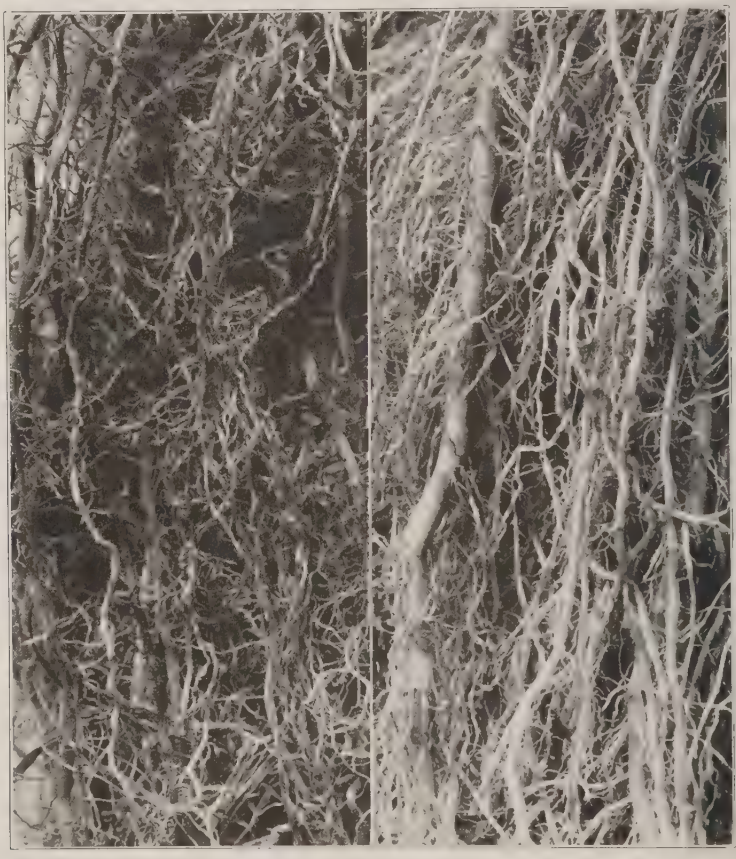


FIG. 26.—SUSCEPTIBILITY AND RESISTANCE TO ROOT ROT

Portions of two root systems, the one on the left being very susceptible to root rot and the other highly resistant.

presents data from an inoculation experiment in which disease-susceptible, open-pollinated strains were compared with an open-pollinated strain that had been selected for disease resistance for a number of years. The field plantings were made under conditions which Dickson has shown to be favorable for injury from *G. saubinetii.* Inoculation with this organism in plantings following virgin prairie sod reduced the mean yield of sound corn from susceptible strains 12.5

bushels per acre, with odds of 1249 to 1, while under the same conditions it reduced the yield of sound corn from the good seed only 0.3 bushels per acre, with odds of 1 to 1. Results from the plantings following wheat were in accord with the foregoing results from the plant-

FIG. 27.—HERITABLE DIFFERENCES IN ANCHORAGE OF CORN PLANTS

Certain inbred strains of corn are weakly anchored and consequently blow down easily. Other strains are well anchored and are able to withstand all ordinary wind and rain storms. The performance of such strains has been found to be consistent over a period of years as reported by Koehler, Dungan, and Holbert. Bloomington.

ing following virgin sod, tho the reductions in the disease-susceptible plots were not so pronounced.

Complete resistance or immunity to a majority of the corn rot diseases, however, seems possible only by the recombination of two or more highly resistant and reasonably productive self-fertilized strains

which nick together in a compatible way, an illustration of which is given in Table 15 and Figs. 28 and 29. These data, as well as those reported in Tables 13 and 14, indicate that *genetic factors are as important as environmental factors in determining resistance to Gibberella root rot and seedling blight disease.*

FIG. 28.—A GOOD FIRST-GENERATION CROSS (Left) AND A POOR ONE (Right)

First-generation crosses between self-fertilized strains vary greatly in their ability to stand erect during strong wind storms. Many crosses are very inferior to the original variety, while a few are decidedly superior in every respect. The cross on the left is illustrated also in Fig. 29 and Table 15.

In comparing good, open-pollinated corn with the first-generation cross reported in Table 15, it will be noted that the percentage of inclined plants was reduced from 12.8 percent to 0.1 percent in the cross. The total yield was increased from 90.5 bushels per acre in

FIG. 29.—TWO METHODS OF CORN BREEDING

Above, corn from good, open-pollinated seed; below, corn from the first-generation cross of two compatible and highly resistant inbred strains of the same variety as above (Table 15). Farm of Mr. E. D. Funk, near Bloomington, 1923.

the open-pollinated corn to 117.2 bushels in the first-generation cross. The yield of sound corn was increased from 85.9 bushels per acre to 110.5 bushels. This same cross gave similar results the previous three years. Further data and discussion of disease resistance and its

relation to corn improvement will be found in other sections of this bulletin.

TABLE 13.—VARIATIONS IN YIELD OF STRONG-ROOTED AND WEAK-ROOTED STRAINS, FOLLOWING INOCULATION OF SEED WITH *Gibberella saubinetii*

Inbred strains of yellow dent corn planted May 22, 1923, on brown silt loam on which corn had been grown the previous year, near Bloomington

Character of strain	Number of strains in experiment	Field stand from uninoculated seed	Mean acre yield from uninoculated seed	Reduction following inoculation	Odds
		perct.	*bu.*	*bu.*	
Strong-rooted	18	90.2	64.5	4.7	81:1
Weak-rooted	18	90.0	38.8	10.4	>9999:1
Difference		0.2	25.7		
Odds		2.1	>9999.1		

TABLE 14.—VARIATION IN FIELD STAND AND YIELD FROM DISEASE-SUSCEPTIBLE AND FROM DISEASE-RESISTANT STRAINS, FOLLOWING INOCULATION OF SEED WITH *Gibberella saubinetii*

Open-pollinated yellow dent corn grown on two fields of brown silt loam, near Bloomington, 1921

Character of strain	Number of plots	Mean percentage field stand from—		Mean acre yield of sound corn from—			
		Uninoculated seed	Inoculated seed	Uninoculated seed	Inoculated seed	Reduction	Odds
Virgin Prairie Sod							
(*Pl. May 11*)		*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	
Good	8	97.8	92.4	75.5	75.2	0.3	1:1
Disease-susceptible	8	92.5	78.5	59.1	46.6	12.5	1249:1
Corn 1918, Oats, 1919, Wheat 1920							
(*Pl. May 10*)							
Good	8	98.6	93.6	68.8	67.1	1.7	3:1
Disease-susceptible	8	90.8	85.4	53.6	45.6	8.0	117:1

TABLE 15.—COMPARATIVE FIELD PERFORMANCE OF CORN GROWN FROM A GOOD SELECTION OF OPEN-POLLINATED SEED AND FROM FIRST-GENERATION HYBRID SEED OF COMPATIBLE, DISEASE-RESISTANT, INBRED STRAINS DERIVED FROM THIS SAME OPEN-FERTILIZED STRAIN

Bloomington, 1923

Nature of corn	Number of plots	Field stand	Barren stalks	Ears rotted	Ears immature	Acre yield	
						Total	Sound
		perct.	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*
Open-pollinated	10	88.5	14.2	3.3	0.6	90.5	85.9
F_1 of disease-resistant, inbred strains	10	94.7	0.0	1.8	3.9	117.2	110.5

PART II

PHYSICAL CHARACTERS OF SEED EARS ASSOCIATED WITH SEED INFECTION AND NONINFECTION

GENERAL APPEARANCE OF SEED EARS AN INDEX TO SEED CONDITION

In the preceding section the causes and symptoms of corn rot diseases were described for the corn plant as a whole; in this section it is proposed to discuss in detail those physical characters of the ear that are likely to indicate the presence or absence of these disease organisms. Very early in the corn-disease work it was found that some ears were much more diseased than others when tested on the germinator. When the less-diseased ears were separated from the more-diseased ears and comparisons were made between the two groups, character by character, certain differences were detected which were believed to be significant, and later studies have confirmed this belief. The great advantage of a knowledge of these significant characters, when selecting corn for seed, is clearly apparent.

Since these differences may not always be confined to any single character, such as luster of ear, nature of shank attachment, character of endosperm, or kernel indentation, there is much advantage in considering a number of characters when selecting ears for seed.

Certain single characters, perhaps because of their conspicuousness, have received undue emphasis as criterions of field performance. While, as will be shown, it may be essential to continue to emphasize them as a basis for discarding ears, it is not safe, on the contrary, to assume that because an ear fails to show some one undesirable character it will prove desirable for seed. For instance, while an ear that is starchy should be discarded, since the chances for its proving good are small, the absence of starchiness does not insure good seed—other characters also must be considered.

SOUND SHANK ESSENTIAL TO NORMAL MATURITY

The shank is a very important organ of the corn plant. It not only supports the ear but is the structure thru which food materials are conducted to the ear. Surrounded by both leaf sheath and husks, it usually is encased in a film of moisture. Both dew and rain, as well as pollen and dust, are retained in the cavities surrounding the shank. Thus fungus spores lodging near the base or middle of the shank have an environment very favorable for germination and growth. This fungous growth not infrequently may start on the outside of the shank, invade its tissues, and cause local infections. The extent of infection depends on several factors, chief of which are the nature of the fungi and the resistance of the plants attacked.

If the shank is weakened in any way, either by mechanical injuries or by physiologic disturbances in the plant, it usually is more readily invaded by fungi. When weakened by local rotting, the shank often breaks or crumples under the weight of the ear (Fig. 30) and

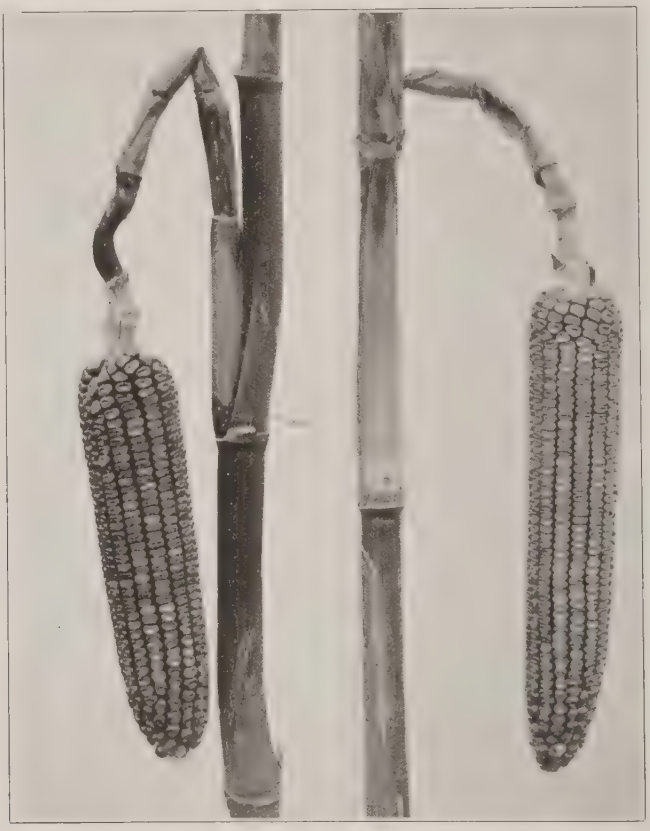


FIG. 30.—BROKEN AND ROTTED SHANKS

When weakened by local rotting, the shank often breaks or crumples under the weight of the ear and no longer is able to function normally. Such injuries frequently are the cause of light, chaffy ears, tho where the injuries occur late in the development of the ear, the reduction in quality may not be so apparent

no longer is able to function normally. Such injuries frequently are the cause of light, chaffy ears that would not be considered for seed. But where the injuries occur late in the development of the ear, the reduction in quality of grain may not be so apparent. If the infecting organism is *Diplodia zeae,* the shank and the butt of the ear may be badly rotted.

FIG. 31.—HEALTHY SHANK CONTRASTED WITH TWO DISEASED SHANKS

At the left, a shank showing bright, healthy condition; center, dark vascular bundles associated with Cephalosporium; at the right, a shredded condition indicating that the ear came from a rotted and prematurely dead shank.

PLATE IV

A A clean, sound shank is an important consideration in the selection of good seed corn.

B Slightly pink shank.

C Pink shank

D Brown shank

E Shredded shank

F Moldy shank

Good seed ears have bright clean shanks or shanks with only slight discoloration.

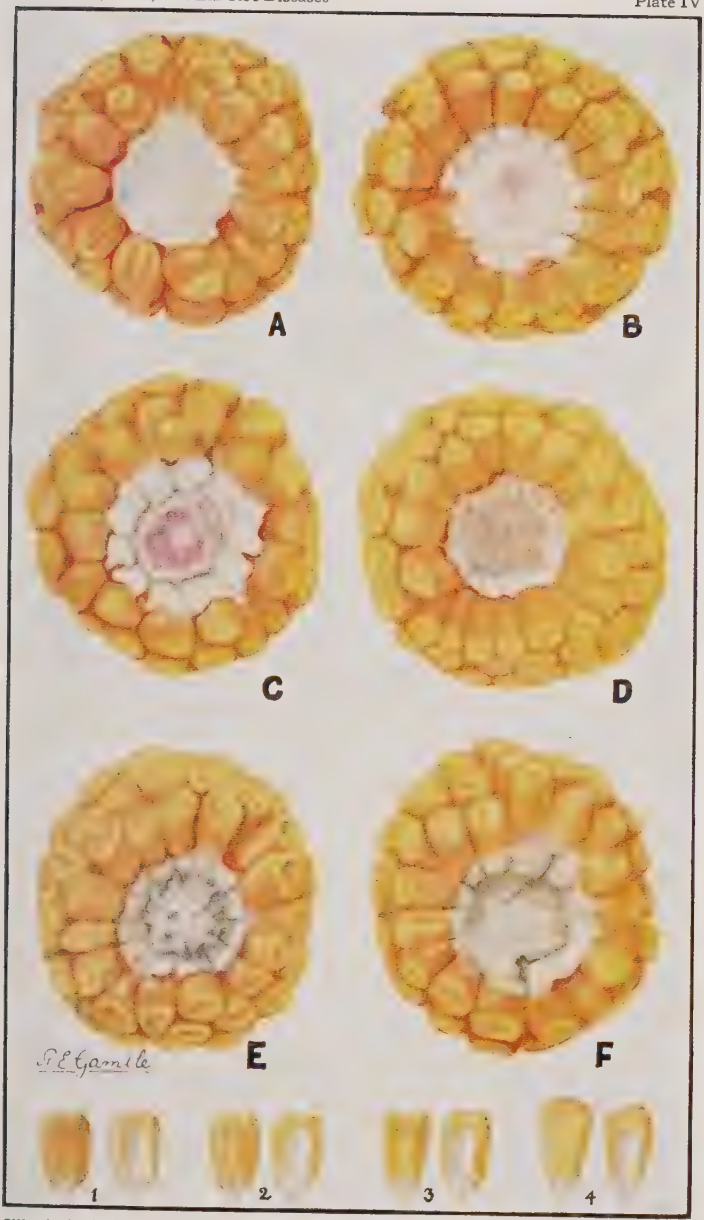
1 Horny seed

2 Moderately horny seed

3 Moderately starchy seed

4 Starchy seed

Disease resistance has been found to be rather generally associated with seed from apparently healthy plants that is nearly disease-free, horny, and shows vigorous germination.



Illinois Agricultural Experiment Station

ROTTED AND BADLY DISCOLORED SHANKS ASSOCIATED WITH POOR SEED CONDITION

Ears selected from plants with rotted or partially rotted shanks have a more or less discolored or shredded shank attachment (Fig. 31 and Plate IV). The kernels on ears with such shank attachments may or may not actually be infected. Judged on the basis of viability, vigor, and freedom from infection, the percentage of desirable seed ears with badly discolored or shredded shanks is comparatively low. Altho some badly diseased ears are found with bright shank attachments, the percentage of such ears also is low. *The data indicate that good seed ears have bright, clean shanks or shanks with only slight discolorations* (Plate IV).

COLORED SHANKS NOT NECESSARILY AN INDICATION OF SEED INFECTION

There is much variation in color and in intensity of color of cob interiors either when viewed in cross-section after the cobs have been broken or when viewed in longitudinal section after they have been sawed longitudinally (Plate V). Variations prevail in most open-pollinated strains of corn, even in those that have been selected rather closely for several years. It seems probable in many cases that red, pink, and brown colorings in the shank are due simply to lodgment in the shank attachment of the same pigment found in the vascular

TABLE 16.—PERCENTAGE OF COBS WITH DIFFERENTLY COLORED VASCULAR CYLINDERS From good-seed composites, Fusarium-infected composites, and Diplodia-infected composites selected for planting in 1923

Relative amount of coloration in vascular cylinder in interior of cob	Seed composites		
	Nearly disease-free (324 ears)	Fusarium-infected (145 ears)	Diplodia-infected (280 ears)
	perct.	*perct.*	*perct.*
None	35.5	15.9	8.3
Slight to moderate	38.6	33.1	50.3
Considerable	25.9	51.0	41.4

cylinder of the cob and do not indicate infection. *Hence, in observing the nature of the shank attachment for the selection of seed, it is very important to distinguish between normal colorations and discolorations resulting from decayed tissues.*

During the spring of 1923, a study was made of the color of the vascular cylinder of cobs taken from the standard composites. Some of these data are reported in Table 16. In the nearly disease-free composite (Table 16), the different degrees of coloration (Plate V) were fairly evenly divided, there being 35.5 percent with no coloration, 38.6 percent with a slight to moderate coloration, and 25.9 percent with a considerable coloration. In both the Fusarium-infected

PLATE V

A, B, C Cob interiors of good seed ears.
In the coloring of the interior cob, considerable natural variation occurs. In some ears the coloration extends to the point of attachment between cob and shank, and thus gives the shank attachment a pink or brown appearance. In such cases pink or brown shanks are normal.

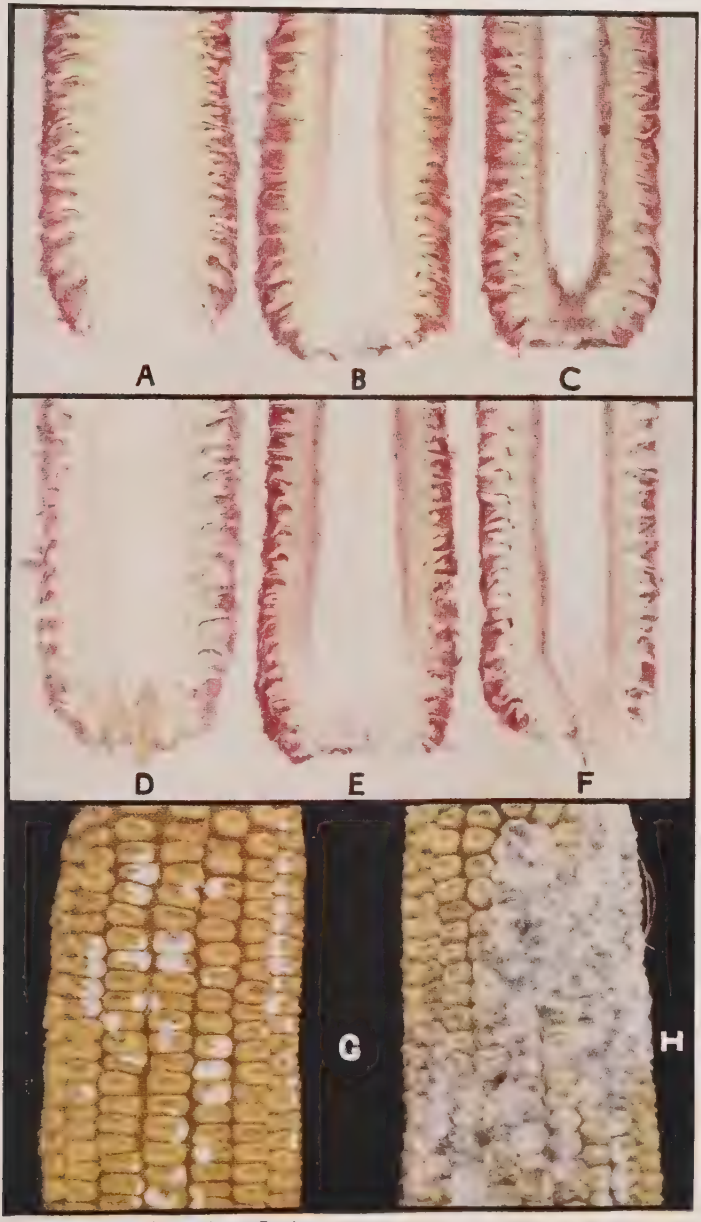
D, E, F Cob interiors of undesirable seed ears.
Note that discolorations at the butts of cobs are due to rotting of the tissues.

Where shank discolorations and shreddings are plainly the result of decayed tissue, the seed value of such ears is very questionable, especially when considered from the standpoint of disease resistance.

G Ear of corn from highly resistant strain that had been injured by earworms.

H Ear of corn from susceptible strain that had been injured by earworms.

There are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection.



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general experience of corn breeders indicate that it is highly desirable, from the standpoint of freedom from infection, that the tips of ears should be well covered by the husks as a protection from the weather and fungus infection.

SMOOTH TO MODERATELY DENTED CORN ASSOCIATED WITH DISEASE RESISTANCE AND HIGH YIELD

From the standpoint of best yields and quality, the evidence of much experimentation favors long, smoothly dented ears, with large well-developed kernels of medium depth. It has been found in these investigations, covering a period of years, that careful testing for viability, vigor, and freedom from disease has almost invariably resulted in the selection of corn of medium smooth to smooth indentation, regardless of source and previous breeding. Such a statement does not imply that ears of smooth indentation have always been free from infection or even relatively disease-free. Some smooth corn is badly diseased and decidedly inferior in quality.

Comparatively few ears of rough indentation have been found to pass repeated germination tests that considered vigor and freedom from disease. Rough ears that have passed such tests at this Station have proved to be rather susceptible to ear rots in the field. They also have shown no superiority in yielding ability to the ears more smoothly dented.

EARS WITH STARCHY KERNELS UNDESIRABLE FOR SEED PURPOSES

Kernel structure and composition, as determined physically by the quality of vitreous, or horny, endosperm (Plate IV), is closely correlated with kernel indentation in most commercial varieties of dent

TABLE 17.—YIELDS FROM NEARLY DISEASE-FREE HORNY SEED AND FROM NEARLY DISEASE-FREE AND DISEASED STARCHY SEED

Average of 25 experiments covering a period of seven years 1917-1923

Kind of seed	Acre yield		Reduction in yield from starchy seed	
	Horny	Starchy		
	bu.	*bu.*	*bu.*	*perct.*
Nearly disease-free	65.1	59.4	5.7	8.8
Diseased	78.6	58.2	20.4	26.0

corn in the corn belt. Altho there are smooth ears that are starchy, and rough ears that are horny, this seems to be the exception rather than the rule. In general, roughly dented kernels are decidedly more starchy and lighter in specific gravity than those more smoothly dented.

Ears showing infection with *Fusarium moniliforme* and *Diplodia zeae* and those affected with scutellum rot are usually much more starchy than those free from infection.

The behavior, under different conditions, of corn grown from ears with horny kernels and from ears with starchy kernels (Plate IV) has been studied experimentally. *The data from these experiments extending over a period of seven years* (Table 17), *together with the fact that by far the greater part of starchy seed in seed stocks in the corn belt is likely to be more or less diseased, justify the discarding of starchy ears for seed purposes.*

SELECT ONLY EARS WITH BRIGHT, RICH LUSTER

Disease-free ears of good viability and vigor that have matured normally on healthy plants have a bright, rich luster. On the other hand, ears that have come from root-rotted and stalk-rotted plants usually present a dry, dull appearance after curing. This difference in luster is particularly apparent when disease-free and diseased ears are compared side by side. Considerable experience in comparing ears known to be infected and ears known to be free from infection is necessary to fix the proper standard of luster in the mind of the worker, but when once established, this difference in physical appearance may be used to great advantage as one determining factor in the selection of seed corn.

DISCARD EARS WITH DULL-APPEARING KERNELS

Brightness, or luster, of the germ side of shelled corn is a physical character that has long been used by veteran corn growers in selecting seed. The studies, in connection with these investigations, show that altho some badly infected ears may have bright kernels, nearly disease-free seed very seldom contains dull kernels.

TABLE 18.—YIELDS OF CORN FROM BRIGHT-TIPPED AND FROM BROWN-TIPPED, NEARLY DISEASE-FREE, HORNY SEED

Average of 8 experiments in 1921

Acre yield		Reduction in yield from brown-tipped kernels	
Bright-tipped kernels	Brown-tipped kernels		
bu.	*bu.*	*bu.*	*perct.*
69.6	65.8	3.8	5.5

Altho most ears with discolored or brown kernel tips are likely to be infected, there are ears of horny composition with kernels decidedly brown on the germ side that show no evidence of being infected when tested on the germinator in the usual way. The seed value of such ears was the subject of a series of experiments reported in Table 18. Notwithstanding lack of positive evidence on the germinator of infection with some kernels colored on the germ side, the *field data are decidedly in favor of the selection of ears whose kernels are bright in every respect.*

PART III

SUSCEPTIBILITY AND RESISTANCE TO ROT DISEASES

That certain ear characters are associated with infection or non-infection of the seed with disease organisms—in other words, that the general appearance of seed ears is an index to the condition of the seed—was shown in the preceding section. Hence, careful inspection of ears is effective in securing disease-free seed corn.

What is wanted, however, is not merely disease-free seed, but *disease-resistant* seed. Disease-freedom and disease-resistance are not synonymous terms. An ear may be entirely free from disease as determined by a germination test and yet be susceptible, that is, capable of infection, or lacking the power to resist infection, when planted on infested soil. Rough, starchy ears, for example, are sometimes found that show no disease whatever, and yet are susceptible. They have *escaped* infection for one reason or another. Disease-escape is not the same as disease-resistance. Disease-resistance is an inherent quality by virtue of which a strain can either resist infection altogether or can hinder or prevent further development of the organism after infection has occurred. The purpose of this section is to present data demonstrating the existence of this desirable quality in some strains and to emphasize its importance.

The common occurrence thruout the corn belt of many hills of corn similar to the one illustrated in Plate VI suggests at once the idea that corn plants vary in their degree of susceptibility to the rot diseases. In most commercial fields, at least where corn follows corn in the rotation, it is not difficult to find hills in which the roots, crown, and stalk of one plant are badly affected, while another plant in the same hill apparently is not affected. This occurrence of apparently healthy and badly diseased plants in the same hill is evidence that some plants must possess considerable resistance to these diseases.

In the germination laboratory, also, has been found abundant evidence of variation in susceptibility and resistance to certain of these diseases. Germinating kernels from some ears within a given lot may be entirely overrun with *Rhizopus spp.* and other fungi, while adjacent kernels from other ears of the same seed lot may remain free from the attack of these organisms. Again, some lots of corn on the germinator may be covered with fungous growth, while other lots of corn on the same tray and germinated under the same conditions may be entirely free from such growth, even when spores of *Rhizopus spp.* are sprayed on the kernels.

EXPERIMENTS SHOWING THAT DIFFERENT STRAINS VARY IN DEGREE OF SUSCEPTIBILITY AND RESISTANCE

In one of the inoculation experiments conducted in 1919, all the ear-rows were planted with seed selected from apparently healthy, open-pollinated plants. In a germinator test, the seedlings from half

TABLE 19.—YIELDS OF CORN FROM NEARLY DISEASE-FREE SEED SELECTED FROM RESISTANT EAR-ROWS AND FROM APPARENTLY SUSCEPTIBLE EAR-ROWS

Average of 2 experiments in 1920

Condition of seed	Acre yield	Reduction in total yield of corn	
	bu.	*bu.*	*perct.*
Nearly disease-free seed from apparently good plants (field selection)	50.6	.....	.....
Moderately diseased seed from apparently good plants (field selection)	47.1	3.5	6.9
Nearly disease-free seed from resistant ear-rows (selected from inoculation experiment)	52.8	.....	.....
Nearly disease-free seed from susceptible ear-rows (selected from inoculation experiment)	41.4	11.4	27.5

these seed ears had proved nearly disease-free and those from the other half had been vigorous but badly affected with scutellum rot. At planting time, part of the seed was inoculated with *Gibberella saubinetii*. Considerable variation in the effect of this inoculation was noted. Some of the rows grown from nearly disease-free seed proved highly resistant to the inoculation, while others proved susceptible. Rows grown from seed of vigor but badly affected with scutellum rot on the germinator were very susceptible, in the majority of cases, to injury from inoculation.

From the above plantings, typical ears were selected from rows that had proved apparently resistant and from rows that had proved apparently susceptible. In 1920, the seed from these two groups of ears was tested on the germinator and that which proved nearly disease-free was used for planting. Nearly disease-free seed selected from apparently good plants in the field, and moderately diseased seed likewise selected, was also planted. (The moderately diseased seed was affected on the germinator with scutellum rot, but showed no evidence of infection with either *Diplodia zeae* or *Fusarium moniliforme*.) The results, reported in Table 19, indicate that *nearly disease-free seed of a susceptible strain or selection may yield even less than moderately diseased seed selected from apparently good plants of a resistant strain, thus suggesting the advantage of careful plant selection and the value of the germination test in securing seed which will produce plants more highly resistant.*

PLATE VI

A Plant prematurely dead on account of disease.

B Plant maturing normally.

In the diseased plant (A) the leaves are dying or are already dead, and the ear is hanging as the result of a crumpled and rotted shank. Corn produced on such plants is light or chaffy and undesirable for seed purposes.

In the healthy plant (B) the ear is maturing normally while the leaves and stalk are still green. Corn from such plants makes excellent material from which to select good seed.

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CONDITION OF ROOTS AND STALKS OF PARENT PLANTS IMPORTANT CONSIDERATION IN SEED SELECTION

During the fall of 1919 several hundred ears were selected from plants the condition of whose roots and stalks was carefully noted and recorded. All the selections were made from corn growing in the second- and third-year corn following clover or other sod. The following winter ten kernels were tested from each ear at three successive times. On the basis of the germination record thus obtained, the ears that might have been selected for seed by most farmers or seedsmen, were classified as follows:

(1) Nearly disease-free seed from apparently disease-free plants.
(2) Nearly disease-free seed from root- and stalk-rotted plants.
(3) Seed from apparently healthy plants which was 100 percent viable and vigorous in germination, but with 20 percent or more of the seedlings showing scutellum rot on the germinator.

Ears that were obviously undesirable for seed were not included.

From approximately 300 ears of good appearance that had been selected from plants with badly rotted roots and stalks, only ten were found to be vigorous in germination and at the same time free from Diplodia and Fusarium infection and not affected by scutellum rot. Of these ten ears, only two had bright shank attachments, and all ten ears were duller in luster, rougher in indentation, and had less horny endosperm than the disease-free ears from healthy plants.

ON INFESTED SOIL NOT ONLY DISEASE-FREE SEED BUT RESISTANT SEED IS NECESSARY FOR BEST RESULTS

Seed from the above groups of ears was planted across a series of twenty-one soil experimental plots designated as the Limestone Series on the farm of Mr. E. D. Funk. Twelve of these soil plots had been in clover sod for two years, none of the crop being removed the second year. The remaining nine plots were on ground that had produced a crop of spring wheat following corn. The corn crop had been badly diseased and the wheat crop had been so heavily scabbed that it was not harvested. The resulting yields are presented in Table 20.

On the comparatively clean soil, the difference in total acre yield between the disease-free corn from healthy plants and the disease-free corn from badly diseased plants was only 4.0 bushels (85.6 bushels as compared with 81.6 bushels). On heavily infested soil, however, the difference in total acre yield from these two seed lots was 12.6 bushels (79.4 bushels as compared with 66.8). In acre yield of sound corn the differences were greater, namely, 4.8 bushels on the comparatively clean soil and 19.4 bushels on the infested soil.

The corn from nearly disease-free seed selected from apparently healthy plants yielded 6.7 bushels, or 8.2 percent, less sound corn per acre on the heavily infested soil than on the comparatively clean soil (Table 20). No doubt a part of this reduction must have been due to

the lower supply of nitrogen in the plots in this part of the experiment. However, the corn grown from the nearly disease-free seed selected from plants with badly rotted roots and stalks proved to be very susceptible to injury on the heavily infested soil, yielding 21.3 bushels, or 27.7 percent, less sound corn on the infested soil than on the com-

TABLE 20.—SUSCEPTIBILITY OF DIFFERENT SEED SELECTIONS AS DETERMINED BY GROWING ON COMPARATIVELY CLEAN SOIL AND ON HEAVILY INFESTED SOIL

Yellow dent corn planted May 17 on brown silt loam, near Bloomington, 1920

Character of seed	Acre yields				Reduction in marketable corn on heavily infested soil	
	Comparatively clean soil		Heavily infested soil			
	Total	Sound	Total	Sound		
	bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
Nearly diease-free seed from apparently disease-free plants	85.6	81.7	79.4	75.0	6.7	8.2
Nearly disease-free seed from root- and stalk-rotted plants	81.6	76.9	66.8	55.6	21.3	27.7
Standard diseased composite used in 1920 (mostly scutellum rot)	74.8	69.7	61.8	53.2	16.5	23.7
Seed selected from standing apparently disease-free plants; 100 percent in viability, but 20 percent of germinated seedlings showed scutellum rot	79.6	75.2	62.7	55.2	20.0	26.6

paratively clean soil. Moreover, it yielded no better than corn grown from seed lots affected with scutellum rot, which also were very susceptible to injury.

These data, together with those presented in Table 19, show that disease-free seed selected from diseased plants is very likely to produce plants more or less susceptible to the corn rot diseases.

CORN FROM STARCHY KERNELS MORE SUSCEPTIBLE TO DISEASE THAN CORN FROM HORNY KERNELS

During the winter of 1920-1921 two nearly disease-free composites differing widely in character of endosperm were prepared, the one horny and the other starchy. Each composite included kernels from approximately 75 ears. These seed lots were planted on duplicate plots following clover and following corn in a rotation of corn, corn, spring grains, and clover. The yield data are given in Table 21.

Altho the corn grown from nearly disease-free starchy seed was practically equal in yield to that from the nearly disease-free horny

seed on the plot following clover, the corn grown from the same lot of starchy seed was decidedly inferior in yielding ability on the infested soil following corn, where soil conditions were less favorable.

Similar horny and starchy composites representing a large number of ears were prepared for planting in 1922. Nearly disease-free starchy ears were even more difficult to obtain than they had been the

TABLE 21.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF NEARLY DISEASE-FREE STARCHY SEED AND NEARLY DISEASE-FREE HORNY SEED AS DETERMINED BY GROWING ON CLEAN SOIL AND ON INFESTED SOIL

Yellow dent corn grown in duplicate plots on soil of medium fertility, University South Farm, Urbana, 1921

Character of seed	Acre yield		Reduction following planting on infested soil	
	Comparatively clean soil (following clover)	Infested soil (following corn)		
	bu.	*bu.*	*bu.*	*perct.*
Horny	73.5	63.4	10.1	13.7
Starchy	71.1	56.8	14.3	20.1
Horny	70.7	66.0	4.7	6.6
Starchy	68.6	56.1	12.5	18.2

previous year. These two composites were used in an inoculation experiment conducted on very fertile soil on which a crop of corn had been grown in 1921. Previous to that time the land had been virgin prairie sod. Seed for part of the experiment was inoculated by soaking it for about thirty minutes, immediately before planting, in a water suspension of young conidia of *Gibberella saubinetii*. The yield data are given in Table 22.

TABLE 22.—COMPARATIVE SUSCEPTIBILITY OF CORN GROWN FROM NEARLY DISEASE-FREE STARCHY SEED AND FROM NEARLY DISEASE-FREE HORNY SEED, TO INOCULATION AT PLANTING TIME WITH A PURE CULTURE OF *Gibberella saubinetii*

Yellow dent corn planted May 26 and 27 on brown silt loam of high fertility, near Bloomington, 1922

Character of seed	Number of replications	Mean acre yield				Reduction in inoculated plots					
		Uninoculated		Inoculated		Total			Sound		
		Total	Sound	Total	Sound						
		bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Horny	12	107.6	100.9	102.6	97.8	5.0	4.6	21:1	3.1	3.1	3:1
Starchy	6	109.6	98.5	85.2	80.0	24.4	22.3	>9999:1	18.5	18.8	>9999:1

In the uninoculated part of the experiment, there was little difference in the total yields of corn grown from the horny seed and the starchy seed, the results being 107.6 bushels with the horny as compared with 109.6 bushels with the starchy seed. The two lots of corn

were, however, affected very differently by the inoculation of the seed. The total yield of corn from the nearly disease-free horny seed was reduced only 5.0 bushels by inoculation, or 4.6 percent, while the yield from the nearly disease-free starchy seed was reduced 24.4 bushels, or 22.3 percent. Differences in yields of sound corn in this experiment are practically in accord with the above differences in total yields.

TABLE 23.—YIELDS FROM VARIOUS STRAINS OF YELLOW DENT CORN SHOWING VARIATIONS IN PROPORTION OF UNMARKETABLE EARS

Experiments conducted on brown silt loam at various points in Illinois, 1920-1922

Year	Location	Number of strain	Character of strain	Acre yield			
				Total	Sound	Unmarketable	
				bu.	*bu.*	*bu.*	*perct.*
1920	Bloomington...	1	Susceptible.....	45.4	30.4	15.0	33.0
	Bloomington...	2	Good.....	64.4	56.1	8.3	12.9
	Bloomington...	3	Susceptible.....	56.3	40.0	16.3	29.0
	Bloomington...	4	Good.....	60.2	54.0	6.2	10.3
1921	Bloomington...	5	Susceptible.....	104.5	67.7	36.8	35.2
	Bloomington...	6	Good.....	107.8	84.2	23.6	21.9
	Bloomington...	7	Susceptible.....	78.3	51.5	26.8	34.2
	Bloomington...	8	Good.....	90.6	72.0	18.6	20.5
	Bloomington...	9	Susceptible.....	79.4	40.8	38.6	48.6
	Bloomington...	10	Good.....	78.3	61.5	16.8	21.5
	Bloomington...	11	Susceptible.....	71.4	32.5	38.9	54.5
	Bloomington...	12	Good.....	76.4	53.0	23.4	30.6
	Bloomington...	13	Susceptible.....	70.7	43.9	26.8	37.9
	Bloomington...	14	Good.....	82.5	65.5	17.0	20.6
1922	Bloomington...	15	Susceptible.....	102.8	93.6	9.2	8.9
	Bloomington...	16	Good.....	105.9	101.2	4.7	4.4
	Bloomington...	17	Susceptible.....	98.4	85.9	12.5	12.7
	Bloomington...	18	Good.....	101.6	94.2	7.4	7.3
1922	Pekin.....	19	Susceptible.....	67.5	54.7	12.8	19.0
	Pekin.....	20	Good.....	72.2	65.6	6.6	9.1
1922	Urbana.....	21	Susceptible.....	48.9	37.3	11.6	23.7
	Urbana.....	22	Good.....	54.5	46.6	7.9	14.5
	Urbana.....	23	Susceptible.....	53.4	42.9	10.5	19.7
	Urbana.....	24	Good.....	54.1	46.0	8.1	15.0

These differences in resistance and susceptibility to injury from seed inoculation with *G. saubinetii,* one of the organisms associated with the corn rot diseases, indicate that corn grown from nearly disease-free starchy seed is less resistant than corn from nearly disease-free horny seed, not only to pure-culture inoculations but also to injury under unfavorable soil conditions that exist where corn follows corn in the rotation. In many instances corn from such starchy

seed has proved to be inferior in yielding ability even on soil of high fertility where an approved rotation and system of farming has been practiced for several years. *Thus it is evident that starchy seed, regardless of its germination record, is very likely to produce corn more or less susceptible to the attack of certain parasitic fungi and to injury from unfavorable weather or soil conditions.*

The above statement does not imply that horny seed always is likely to produce corn resistant to these diseases. Neither does it imply that all ears with horny kernels are desirable for seed purposes. Horny seed may carry considerable infection with *Diplodia zeae, Fusarium spp.,* and *Cephalosporium acremonium.* Seed that is infected with disease-producing organisms, regardless of kernel composition, may produce corn very susceptible to injury under some conditions. *The important consideration is disease resistance, a condition which up to the present time the authors have not found associated with starchy seed or infected horny seed, but rather generally associated with seed from apparently healthy plants that shows vigor and freedom from disease on the germinator and that is horny in composition.*

WIDE RANGE IN VALUE OF COMMERCIAL STRAINS

During these investigations it became evident that the many strains of yellow dent corn, as they are selected and maintained on various farms thruout the corn belt, differ widely in their yielding ability and resistance and susceptibility to disease. Data on which the above statement is based are presented in Table 23.

The differences in the proportion of unmarketable corn (rotted and chaffy ears and small nubbins) where the different strains were grown under the same soil and climatic conditions are very significant. In 1921, the year in which there was much damage from ear rots, two strains, Nos. 9 and 10, produced total acre yields of 79.4 and 78.3 bushels, respectively. Yet the difference in yield of sound corn was 20.7 bushels, or 40.8 bushels as compared with 61.5 bushels. Strain No. 9 produced 38.6 bushels of damaged corn, while strain No. 10 produced only 16.8 bushels. Since these strains were grown on adjoining plots receiving the same soil treatment, these large differences cannot be explained on the basis of differences in climatic or soil conditions; obviously they were due to inherent differences in degree of disease resistance and susceptibility possessed by the two strains.

Such a wide variation in resistance and susceptibility no doubt is one very important factor in determining the comparative yields of different strains from year to year. When all the conditions are favorable thruout the growing season, a strain of corn that is normally low in yielding ability may produce a very satisfactory yield; but the same strain under slightly adverse conditions may produce a very low yield.

EXPERIMENTS SHOWING THAT CERTAIN PHYSICAL CHARACTERS OF SEED EARS ARE ASSOCIATED WITH SUSCEPTIBILITY AND RESISTANCE AS WELL AS WITH INFECTION AND NONINFECTION

In Part II it was shown that there are many differences in physical appearance between seed ears that are nearly disease-free and of good viability and vigor in germination, and ears that are infected or ears

FIG. 33.—POOR SEED

Representative moderately diseased ears selected for experimental purposes from ears supplied by J. R. McKeighan and Son, Yates City. (Compare with Fig. 34.)

the progeny of which will prove susceptible to the corn rot diseases. Outstanding examples of these differences in physical appearance are illustrated in Figs. 33 and 34.

Often, however, ears that will produce susceptible plants are, in some particular character such as luster, nature of shank attachment, exposure of tip of ear, character of endosperm, or kernel indentation, so like ears that will prove resistant that no distinction based on that character alone can be made between them, but they seldom are alike

in *all* the above mentioned characters. In view of the fact that such differences in physical appearance do exist and that ears from diseased plants frequently produce plants more or less susceptible to disease and injury under unfavorable soil and weather conditions, a series of experiments was planned during the winter of 1920-1921, to determine the need for considering all the physical characters under discussion in detecting seed ears which produce plants that are comparatively resistant, and those which produce plants that are susceptible.

FIG. 34.—GOOD SEED

Nearly disease-free ears selected for experimental purposes from ears supplied by J. R. McKeighan and Son, Yates City. (Compare with Fig. 33.) It is evident that there are many differences in the physical appearance of nearly disease-free seed ears of good viability and vigor in germination as compared with infected ears and ears the progeny of which is susceptible to the corn rot diseases.

FOUR STRAINS OF YELLOW DENT USED IN EXPERIMENTS

Four widely different strains of yellow dent corn that had been grown in central Illinois for several years were selected as a basis for

these experiments. These were designated as Lots A, B, and C, and the nearly disease-free check. The first three lots of seed (A, B, and C) were furnished by three representative farmers from as many nearby counties. Each lot of seed was typical of the seed these farmers expected to plant.

Altho Lots A and B had not been given much attention from the standpoint of selection, Lot A for several years had been selected early in the field without particular attention to type of plant and had been germinated for viability. Also, in this strain of corn fairly large ears of rough indentation had been given preference.

Lot C had been selected over a period of fifteen years for smooth, horny, rather heavy ears.

The lot of nearly disease-free check seed was from a strain which had received six years' continuous selection for grain production and apparent freedom from disease in the field, and vigor and freedom from infection on the germinator. During this period the strain out of which the nearly disease-free check corn was chosen had become horny in composition and medium to smooth in indentation.

SELECTIONS MADE FOR APPARENT SUSCEPTIBILITY AND RESISTANCE

Selections of *apparently good* seed and *apparently susceptible* seed from each of the first three lots (A, B, and C) were made on the basis of physical characters only, prior to the germination test. No ear was included in the apparently good seed that did not appear to have matured normally and fully on a comparatively healthy plant. Kernels from both ends and from the middle of every ear were examined and those ears showing any evidence of poor seed condition or infection were not included.

The selections of apparently susceptible seed were made up of ears that obviously had been produced on plants more or less affected with the root, stalk, and ear rot diseases. No ears, however, with apparently poor seed condition or heavy infection were included. In Lots A and B the apparently susceptible selection was representative of about 90 percent of the entire sample of over 1,000 ears in each case.

Following the selections on the basis of physical appearances, a germination test was made of 30 kernels from each ear. The results indicated that all the selections were reasonably good in viability with the exception of three ears from the apparently susceptible seed from Lot C. These were found to be dead and accordingly were discarded. Representative ears from some of the selections are shown in Figs. 35 and 36.

PLAN OF PLANTING AND INOCULATIONS

The two fields chosen as the site for these studies were adjoining and were similar in soil type, topography, and fertility. One field

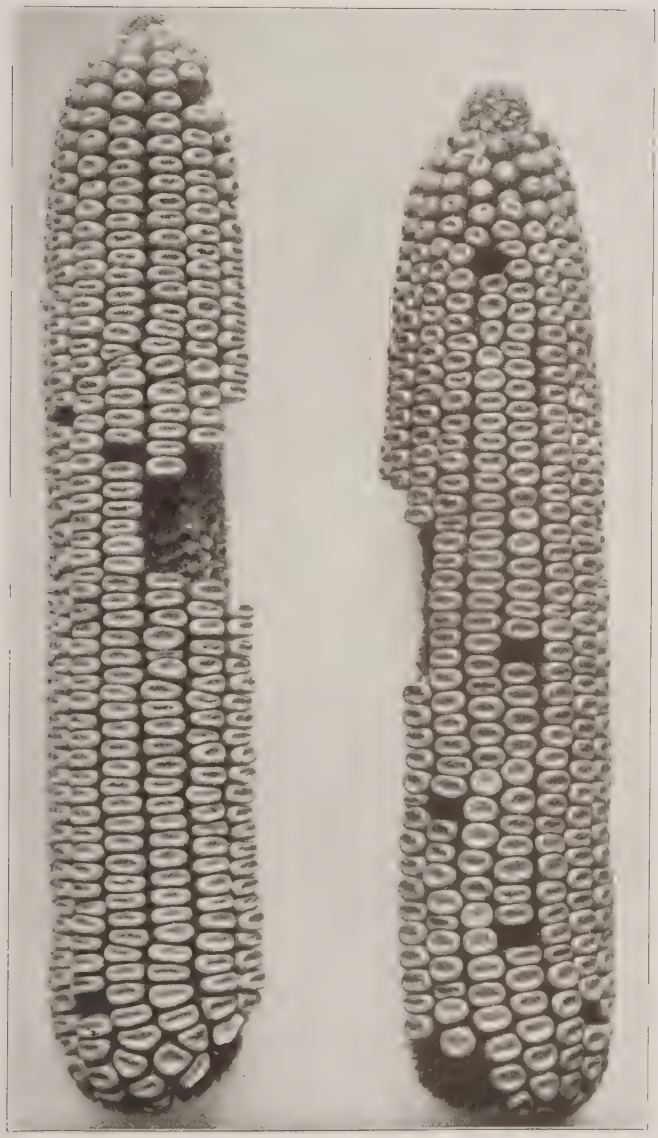

FIG. 35.—REPRESENTATIVE EARS FROM THE GOOD-SEED SELECTION, LOT A

An increase of 10.7 percent in yield of sound corn was secured by selecting seed ears of this type. Attention was given to the physical characters described on page 81.

FIG. 36.—REPRESENTATIVE EARS FROM THE GOOD-SEED SELECTION, LOT C

When proper attention is given to all factors concerned in the selection of good seed corn, no difficulty will be experienced in "smooth" corn "running out." This particular strain of corn has been selected along these lines over a period of years and is conceded to be the highest yielding strain in the community in which it is grown.

was virgin prairie sod. The adjoining field had produced corn six years, oats one year, and wheat one year since the virgin prairie sod was broken in 1913. Both fields were fall plowed. As evidence of the fertility of the soil in the cultivated field it may be stated that the wheat yield the preceding year was approximately 45 bushels per acre.

The seed composites made from the apparently good seed and the apparently susceptible seed selections, together with the composites from all the original ears of each lot of seed, were planted in groups of four rows, the rows running north and south. Every alternate group of four rows was planted with the nearly disease-free check.

In each row, alternate groups of ten hills or rows, in some cases five hills, were inoculated at planting time with *Gibberella saubinetii*, the wheat scab organism, *Fusarium moniliforme*, and *Diplodia zeae*, thus making alternate bands of inoculated and uninoculated plots running east and west in the field. When the corn was about 12 inches high, inoculations with *Cephalosporium acremonium* and *Aplanobacter stewarti* were made by means of hypodermic injections near the crown of the plant. The intervening groups of ten hills or rows were uninoculated and were used thruout the experiment as controls to measure the effect of the inoculations.

An early and a late planting were made on both clean and infested soil, thus making four experiments. These four experiments were identical in arrangement of seed and inoculations, each being made up of 377 plots. The seed planted in each of these small plots was so selected that a few kernels were included from every one of the ears comprizing the composite in question. For example, three kernels from each of the 120 nearly disease-free ears were planted in every plot planted with check seed. The corn was dropped thru specially designed hand planters at the rate of three kernels per hill. All necessary precautions against contamination were taken in connection with planting the inoculated seed. Mean field stands in the check plots ranged from 92.0 percent to 98.9 percent.

GOOD SEED MUCH LESS SUSCEPTIBLE TO DISEASE INJURY

In the above experiments the plants from the apparently good seed and those from the apparently susceptible seed were affected very differently by the pure-culture inoculations, both in the clean soil and in the infested soil. The data are given in Table 24. Data from the experiments on the clean soil are summarized in Table 25.

The selections of apparently good seed were much less susceptible than was the susceptible seed to injury following inoculations with both *Gibberella saubinetii*, a root-rotting organism, and *Cephalosporium acremonium*, an organism whose activities seem to be confined mostly to the stalk. In plantings on clean soil, total yields and yields of sound corn were affected in approximately the same way.

The summaries given in Table 25 show that the yield of sound corn grown from good-seed selections was reduced by inoculation only 5.9, 5.1, and 0.2 bushels, respectively, for each of the three lots of seed. Yields of sound corn grown from apparently susceptible seed selections were reduced 16.3, 17.0, and 12.7 bushels, respectively. Averaging all

TABLE 24.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF CORN FROM APPARENTLY GOOD SEED AND APPARENTLY SUSCEPTIBLE SEED SELECTIONS, TO PURE-CULTURE INOCULATIONS WITH *Gibberella saubinetii* AND *Cephalosporium acremonium*

Yellow dent corn grown on brown silt loam of high fertility, Bloomington, 1921

Source of seed	Apparent character of seed based on physical appearance	Inoculum used	Acre yield				Reduction following inoculation			
			Uninoculated		Inoculated		Total		Sound	
			Total	Sound	Total	Sound				
Clean Soil (Virgin Prairie Sod)										
			bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Lot A	Good	*Gibberella saubinetii*	92.3	72.0	80.6	63.7	11.7	12.7	8.3	11.5
	Susceptible	*Gibberella saubinetii*	88.3	63.4	65.2	43.8	23.1	26.2	19.6	30.9
	Difference		*4.0*	*8.6*	*15.4*	*19.9*				
	Good	*Cephalosporium acremonium*	96.5	66.5	92.3	63.1	4.2	4.4	3.4	5.1
	Susceptible	*Cephalosporium acremonium*	91.2	53.9	75.7	41.0	15.5	17.0	12.9	23.9
	Difference		*5.3*	*12.6*	*16.6*	*22.1*				
Lot B	Good	*Gibberella saubinetii*	81.7	60.6	83.0	63.0	−1.3	−1.6	−2.4	−4.0
	Susceptible	*Gibberella saubinetii*	79.5	57.6	62.7	43.9	16.8	21.1	13.7	23.8
	Difference		*2.2*	*3.0*	*20.3*	*19.1*				
	Good	*Cephalosporium acremonium*	86.0	60.2	78.3	47.6	7.7	9.0	12.6	20.9
	Suspectible	*Cephalosporium acremonium*	82.0	51.7	57.6	31.4	24.4	29.8	20.3	39.3
	Difference		*4.0*	*8.5*	*20.7*	*16.2*				
Lot C	Good	*Gibberella saubinetii*	81.8	60.0	80.8	63.3	1.0	1.2	−3.3	−5.5
	Susceptible	*Gibberella saubinetii*	80.4	57.5	74.7	53.1	5.7	7.1	4.4	7.7
	Difference		*1.4*	*2.5*	*6.1*	*10.2*				
	Good	*Cephalosporium acremonium*	81.6	57.6	73.8	53.9	7.8	9.0	3.7	6.4
	Susceptible	*Cephalosporium acremonium*	79.4	49.8	55.4	28.8	24.0	30.2	21.0	42.2
	Difference		*2.2*	*7.8*	*18.4*	*25.1*				
Nearly disease-free check		*Gibberella saubinetii*	91.0	73.1	89.0	71.2	2.0	2.2	1.9	2.6
		Cephalosporium acremonium	99.7	74.9	87.2	60.9	12.5	12.5	14.0	18.7
Infested Soil										
Lot A	Good	*Gibberella saubinetii*	83.3	62.3	77.4	60.8	5.9	7.1	1.5	2.4
	Susceptible	*Gibberella saubinetii*	75.8	48.6	74.0	49.3	1.8	2.4	−0.7	−1.4
	Difference		*7.5*	*13.7*	*3.4*	*11.5*				
Lot B	Good	*Gibberella saubinetii*	84.3	61.9	74.9	52.4	9.4	11.2	9.5	15.3
	Susceptible	*Gibberella saubinetii*	75.2	53.4	66.8	38.7	8.4	11.2	14.7	27.5
	Difference		*9.1*	*8.5*	*8.1*	*13.7*				
Lot C	Good	*Gibberella saubinetii*	81.2	64.0	74.9	67.1	6.3	7.8	−3.1	−4.8
	Susceptible	*Gibberella saubinetii*	77.3	60.0	69.6	47.7	7.7	10.0	12.3	20.5
	Difference		*3.9*	*4.0*	*5.3*	*19.4*				
Nearly disease-free check		*Gibberella saubinetii*	86.6	67.3	84.7	66.3	1.9	2.2	1.0	1.5

the plots represented in Table 25, inoculations reduced the yield of corn from the good-seed selections only 3.7 bushels, with odds of 9 to 1, while the same inoculations reduced the yield of corn from the susceptible-seed selections 15.4 bushels, with odds of 999 to 1 (Table 26).

TABLE 25.—SUMMARY OF DATA FROM TABLE 24 SHOWING COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF PLANTINGS ON CLEAN SOIL

Source of seed	Character of seed selection	Acre yield				Reductions in sound corn following inoculation	
		Uninoculated		Inoculated			
		Total	Sound	Total	Sound		
		bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
Lot A	Good	94.4	69.3	86.5	63.4	5.9	8.5
	Susceptible	89.8	58.7	70.5	42.4	16.3	27.8
	Difference	4.6	10.6	16.0	21.0	.....	.....
Lot B	Good	83.9	60.4	80.7	55.3	5.1	8.4
	Susceptible	80.8	54.7	60.2	37.7	17.0	31.1
	Difference	3.1	5.7	20.5	17.6	.....	.....
Lot C	Good	81.7	58.8	77.3	58.6	0.2	0.3
	Susceptible	79.9	53.7	65.1	41.0	12.7	23.6
	Difference	1.8	5.1	12.2	17.6	.....	.....

On none of the plots on clean soil on which uninoculated plants were grown were differences in total yields from the good-seed and from the susceptible-seed selections very large (Table 24). Differences in total yield of corn grown from the same seed lots on the inoculated plots, however, were very significant, ranging from 6.1 to 20.7 bushels. Differences in yield of sound corn in the inoculated plots of the same experiment ranged from 10.2 to 25.1 bushels.

TABLE 26.—SUMMARY OF DATA FROM TABLE 24 SHOWING COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF APPARENTLY GOOD SEED AND APPARENTLY SUSCEPTIBLE SEED SELECTIONS

Apparent character of seed based on physical appearance	Number of replications	Mean acre yield of sound corn		Reduction in sound corn following inoculation		
		Uninoculated	Inoculated			
		bu.	*bu.*	*bu.*	*perct.*	*odds*
Good	6	62.8	59.1	3.7	5.9	9:1
Susceptible	6	55.7	40.3	15.4	27.7	999:1

CORN ROT DISEASES MAY SERIOUSLY AFFECT QUALITY OF GRAIN WITHOUT REDUCING THE TOTAL YIELD

Total yields from apparently good-seed and from apparently susceptible-seed selections were affected in about the same degree by inoculations with *G. saubinetii* when grown on infested soil.

In Lot A corn grown from apparently susceptible seed proved to be very susceptible to injury from the unfavorable conditions encountered in the infested soil. The yield of sound corn was reduced from 63.4 bushels in clean soil to 48.6 bushels in infested soil. Seed inoculation with *G. saubinetii* did not cause any further reduction. In Lots B and C on the infested soil, inoculations with this organism caused considerably more reduction in yield of sound corn in plots grown from apparently susceptible seed than in those grown from apparently good seed, the figures being 14.7 and 12.3 bushels as compared with 9.5 and an increase of 3.1 bushels. In Lot C the difference between the two seed selections in yield of sound corn in the uninoculated plot was 4.0 bushels, while in the inoculated plot the difference was 19.4 bushels, almost five times as much.

These data emphasize the serious effect root rot diseases may have in increasing the percentage of chaffy ears, rotted ears, and nubbins, thus reducing the quality of the yield. These differences between strains in resistance and susceptibility are very significant. Furthermore these differences could not be measured by total yield only; the importance of taking cognizance of quality, as well as quantity, of yield is clearly evident.

STRAINS OF CORN NOT EQUALLY RESISTANT AND SUSCEPTIBLE TO ALL CORN ROT DISEASES

The difference in the effect following the inoculations with *G. saubinetii* and with *C. acremonium* on corn grown from the nearly disease-free checks is worthy of consideration. On the clean soil the organism affecting the roots (*G. saubinetii*) caused a reduction of only 1.9 bushels in yield of sound corn. Six years' continuous plant and germinator selection apparently resulted in isolating an open-pollinated strain of corn highly resistant to this organism under the usual field conditions. However, this same strain of corn was susceptible to inoculation with *C. acremonium*, an organism infecting the vascular bundles of the stalk. Plants and ears affected with this organism are not always easily avoided in the selection of good seed. During the earlier years of these investigations, when the symptoms of the black-bundle disease were not understood and the causal organism not known, it is very likely that many seed ears infected with *C. acremonium* were included in the seed stock used for propagating this strain of corn.

HIGH YIELDS AND DISEASE RESISTANCE EQUALLY IMPORTANT IN DEVELOPING BETTER SEED CORN FOR ILLINOIS

It would seem, therefore, that a program which aims to develop productive strains of corn possessing high degrees of disease resistance must consider all the factors concerned. Yield data from corn grown

from the nearly disease-free check at many places in Illinois and under adverse conditions indicate, however, that continuous selection for production and freedom from disease in the field and vigor and freedom from infection on the germinator has been worth while and profitable. Complete resistance to all known diseases and to injury from adverse conditions, combined with high grain production and maturity, probably can be attained only thru recombination of resistant inbred strains whose merit has been carefully determined.

EXPERIMENTS SHOWING THE VALUE OF PHYSICAL APPEARANCE AS A BASIS FOR SEED SELECTION

The experiments reported in the preceding section show that it is possible to choose from the same seed lots, on the basis of physical appearance alone, groups of ears the progeny of which will differ widely in resistance and susceptibility to the corn rot diseases (Table 24). The data also show that the better the strain upon which the selection is practiced, the greater the return for the effort involved, for it is only by selecting from a strain in which there is some corn that is resistant that a strain having a high degree of resistance can be developed.

In the same experiments, corn grown from apparently good seed selected on the basis of physical appearance was compared with corn grown from "original composites." These original composites were made up by removing a few kernels from every ear in each lot when the lot was received and before any selections had been made. Hence they were in each case completely representative of the original lot, containing seed from good ears as well as from ears susceptible to disease.

This comparison, as will be shown later, emphasizes the value of physical selection in securing good seed corn. A large number of ears can be examined in a relatively short time, the best saved, and the poorest discarded. Thus a considerable number of ears can be eliminated from further consideration, and the stock reduced to those ears which will likely prove the best. The time and expense involved in caring for and handling the poor ears are saved, and if a germination test is to be made, the number of ears to be germinated is only a small part of the original supply.

CHARACTERS GIVEN CONSIDERATION IN SELECTING GOOD SEED EARS FOR EXPERIMENT

The selections of apparently good seed represented the best 50 to 90 ears from approximately 1,000 ears in each of the original seed lots (A, B, and C). These good seed ears were chosen in much the

same way that a successful live-stock man would choose the best breeders from a large number of animals. In selecting such animals many points would be considered and each given its proper weight before any individual would be taken for breeding purposes. Likewise, in selecting apparently good seed, due emphasis was given to those characters which have been found to be associated with disease resistance and freedom from infection. The characters given major emphasis were:

Weight and size of ear	Nature of endosperm
Luster	Covering of tip of ear
Appearance of shank attachment	Kernel indentation

Altho only a few of the ears selected were perfect in all these characters, no ears were included that were decidedly deficient in any particular, including such characters as would indicate that the ears had been borne on diseased plants.

FIG. 37.—A WELL-MATURED EAR PRODUCED ON A HEALTHY STALK AND A SOUND, STIFF SHANK

The factors to be considered in the selection of good seed are: character of mother plants, protection by husks, condition of shank attachments, luster of ears, brightness of kernels, composition of kernels, and vigor and freedom from disease on the germinator.

On the basis of the above physical characters alone, the apparently good seed ears were the best ears that could be picked out of each lot of seed. *In general appearance these good seed ears were mid-sized, heavy in weight, bright in luster, moderately horny to horny in kernel composition, and moderately smooth to smooth in indentation. Shank attachments were bright or only slightly discolored, and in no case was there evidence of rotting of the tissues at the butt of the cobb. Tips of the ears had been covered by the husks or had been only slightly exposed, as judged by the appearance of the ear and tip end of the cob. A very high percentage of the ears had bright kernels.*

INOCULATIONS MADE TO TEST RESISTANCE AND SUSCEPTIBILITY

In order to test the relative resistance and susceptibility of these seed selections to corn rot diseases, both the original composite and the selection of apparently good seed from each of Lots A, B, and C were inoculated with pure cultures of *C. acremonium*, *A. stewarti*, and *G. saubinetii*. Inoculations with *C. acremonium* and *A. stewarti* were made by hypodermic injection when the corn was about two feet high. Inoculations with *G. saubinetii* were made by immersing the seed immediately before planting in a spore suspension of the organism.

Data showing the comparative resistance or susceptibility of the original composites and the good-seed selections to inoculations with each of these disease organisms are reported in Table 27 and summarized in Table 28.

GOOD-SEED SELECTIONS MORE RESISTANT THAN ORIGINAL COMPOSITES

In most cases corn grown from good-seed selections was more resistant to inoculation with *G. saubinetti* and to hypodermic inoculations with *C. acremonium* and *A. stewarti* than was corn grown from the original composites (Table 26). Undoubtedly, the different degrees of resistance possessed by corn grown from the original composites and from the good-seed selections are important contributing factors in determining their relative yielding abilities. With every condition favorable, the good-seed selections might not be expected to yield any more than the original composites, but under somewhat adverse conditions, there would be marked differences in yield between the two kinds of seed.

GOOD-SEED SELECTIONS ALSO HIGHER YIELDING THAN ORIGINAL COMPOSITES

Yields from a large number of plots planted with the original composites and the good-seed selections are reported in Table 29 and summarized in Table 30. These data were secured from early and late plantings on both clean and infested soil of high fertility. Data

TABLE 27.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF CORN FROM ORIGINAL COMPOSITES AND APPARENTLY GOOD SEED SELECTIONS, TO PURE-CULTURE INOCULATIONS WITH *Cephalosporium acremonium*, *Aplanobacter stewarti*, AND *Gibberella saubinetii*

Selections from three strains of yellow dent corn, Bloomington, 1921

Source of seed	Character of seed	Date of planting	Soil infestation	Inoculum used	Acre yield				Reduction following inoculation			
					Uninoculated		Inoculated		Total		Sound	
					Total	Sound	Total	Sound				
					bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Lot A	Original composite	May 11	Clean	*Cephalosporium acremonium*	87.9	57.6	77.2	47.3	10.7	12.2	10.3	17.9
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	96.5	66.5	92.3	63.1	4.2	4.4	3.4	5.1
	Increase in yield of good-seed selection over original composite				8.6	8.9	15.1	15.8				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	84.2	51.5	73.3	32.3	10.9	12.9	19.2	37.3
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	74.4	51.5	69.8	49.7	4.6	6.2	1.8	3.5
	Increase in yield of good-seed selection over original composite				−9.8	0.0	−3.5	17.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	86.5	59.3	79.2	56.5	7.3	8.4	2.8	4.7
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	93.1	69.5	80.2	61.5	12.9	13.9	8.0	11.5
	Increase in yield of good-seed selection over original composite				6.6	10.2	1.0	5.0				
	Original composite	May 10	Infested	*Gibberella saubinetii*	78.9	58.1	71.3	50.9	7.6	9.6	7.2	12.4
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	80.3	60.0	74.4	58.0	5.9	7.3	2.0	3.3
	Increase in yield of good-seed selection over original composite				1.4	1.9	3.1	7.1				
Lot B	Original composite	May 11	Clean	*Cephalosporium acremonium*	90.8	49.5	70.9	38.4	19.9	21.9	11.1	22.4
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	86.0	60.2	78.3	47.6	7.7	9.0	12.6	20.9
	Increase in yield of good-seed selection over original composite				−4.8	10.7	7.4	9.2				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	77.0	48.3	80.3	52.4	−3.3	−4.3	−4.1	−8.5
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	84.4	64.6	93.6	59.8	−9.2	−10.9	4.8	7.4
	Increase in yield of good-seed selection over original composite				7.4	16.3	13.3	7.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	83.1	61.4	73.8	51.8	9.3	11.2	9.6	15.6
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	81.1	60.4	83.0	61.7	−1.9	−2.3	−1.3	−2.2
	Increase in yield of good-seed selection over original composite				−2.0	−1.0	9.2	9.9				

TABLE 27.—*Concluded*

Source of seed	Character of seed	Date of planting	Soil infestation	Inoculum used	Acre yield				Reduction following inoculation			
					Uninoculated		Inoculated		Total		Sound	
					Total	Sound	Total	Sound				
					bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
	Original composite	May 10	Infested	*Gibberella saubinetii*	75.5	51.7	64 2	45 7	11.3	15 0	6 0	11 6
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	81.3	58 5	74 9	54 7	6 4	7 9	3 8	6 5
	Increase in yield of good-seed selection over original composite				5 8	6 8	10 7	9 0				
Lot C	Original composite	May 11	Clean	*Cephalosporium acremonium*	72.7	42 8	57 2	30 3	15 5	21 3	12 5	29.2
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	81 6	57 6	73 8	53 9	7 8	9 6	3 7	6 4
	Increase in yield of good-seed selection over original composite				8.9	14 8	16 6	23 6				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	94 0	74 8	78 1	46 1	15 9	16.9	28 7	38.4
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	93 4	68 5	91 7	68 5	1 7	1 8	0 0	0.0
	Increase in yield of good-seed selection over original composite				−0.6	−6.3	13.6	22.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	78 3	58 2	78 2	59.1	0 1	0.1	−0 9	−1.5
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	81 7	62 4	78 7	62 5	3 0	3 7	−0 1	−0 2
	Increase in yield of good-seed selection over original composite				3.4	4.2	0.5	3.4				
	Original composite	May 10	Infested	*Gibberella saubinetii*	80 3	57 4	81 9	54.6	−0 6	−0 7	2 8	4 9
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	81 2	64 0	74 9	67.1	6 3	7 8	−3 1	−4 8
	Increase in yield of good-seed selection over original composite				0.9	6.6	−6.0	12.5				

TABLE 28.—SUMMARY OF DATA PRESENTED IN TABLE 27

Character of seed	Date of planting	Soil infestation	Inoculum used	Mean acre yield				Reduction following inoculation			
				Uninoculated		Inoculated		Total		Sound	
				Total	Sound	Total	Sound				
				bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Original composite	May 11	Clean	*Cephalosporium acremonium*	83.8	50.0	68.4	38.7	15.4	18.4	11.3	22.6
Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	88.0	61.4	81.5	54.9	6.5	7.4	6.5	10.6
Increase in yield of good-seed selection over original composite				4.2	11.4	13.1	16.2				
Original composite	May 28	Clean	*Aplanobacter stewarti*	85.1	58.2	77.2	43.6	7.9	9.3	14.6	25.1
Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	84.1	61.5	85.0	59.3	−0.9	−1.1	2.2	3.6
Increase in yield of good-seed selection over original composite				−1.0	3.3	7.8	15.7				
Original composite	May 11	Clean	*Gibberella saubinetii*	82.6	59.6	77.1	55.8	5.5	6.7	3.8	6.4
Good-seed selection	May 11	Clean	*Gibberella saubinetii*	85.3	64.1	80.6	61.9	4.7	5.5	2.2	3.4
Increase in yield of good-seed selection over original composite				2.7	4.5	3.5	6.1				
Original composite	May 10	Infested	*Gibberella saubinetii*	78.2	55.7	72.1	50.4	6.1	7.8	5.3	9.5
Good-seed selection	May 10	Infested	*Gibberella saubinetii*	80.9	60.8	74.7	59.9	6.2	7.7	0.9	1.5
Increase in yield of good-seed selection over original composite				2.7	5.1	2.6	9.5				

from adjacent plots planted with nearly disease-free check seed are included in this table as a means of comparison.

The good-seed selection produced slightly higher field stands than the original composite in ten of the twelve comparisons reported in Table 29. *Altho a good field stand with reference to quantity is absolutely essential to satisfactory yield, within limits it is not so important as quality of stand as regards vigor and resistance of plants.* Plantings from good-seed selections not only resulted in somewhat better stands, but in stands with higher percentages of strong, vigorous plants. Data previously published indicate that this increase in percentages of strong, vigorous plants contributed much more to the higher yields in those plots than did the slightly increased stands.

Field stands in plots planted with nearly disease-free check seed not only were high, ranging from 95.9 ± 0.5 to 98.2 ± 0.2 percent, but contained very few weak plants.

The increases in yield of sound corn from the good-seed selections over the original composites, of 5.8 bushels on the clean soil and 7.3 bushels on the infested soil, are very significant in terms of the probable errors involved. *These data show that careful physical selection of seed ears may be expected to give profitable increases in yield. The increases in yield of sound corn of the nearly disease-free checks over the good-seed selections also are significant.*

VALUE OF PHYSICAL SELECTION OF SEED EARS LIMITED BY QUALITY OF STRAIN

The selection of seed on the basis of physical appearance has limitations as well as possibilities in that it presupposes, not only a variation in the seed stock, but that some of the ears are good for seed. Some strains of corn, however, are so susceptible to disease and so deficient in those qualities which make for high yield of sound corn that *neither physical selection nor germinator selection can effect any improvement in either quality or quantity of the crop.* Several such strains of yellow dent from different farms thruout the corn belt have been encountered during the course of these investigations. The field data from Lot D, a strain which apparently lacked possibilities for improvement, are reported in Table 31.

CONTINUOUS SELECTION FOR DISEASE RESISTANCE AND INCREASED YIELD MORE EFFECTIVE THAN ONE YEAR'S SELECTION

In developing resistance to the stalk and root rot diseases and an increased productivity, a single year's selection on the basis of physical appearance could not be expected to be so effective as consistent selection toward the same goal over a period of years.

The value of continuous selection toward any one character is well proven in the corn-breeding experiments initiated by Dr. Cyril G.

TABLE 29.—YIELDS FROM ORIGINAL COMPOSITES, FROM SELECTIONS OF APPARENTLY GOOD SEED, AND FROM NEARLY DISEASE-FREE CHECKS

Yellow dent corn grown on brown silt loam of high fertility, near Bloomington, 1921

Character of seed	Date of planting May	Soil infestation[1]	Field stand	Acre yield		Increase in acre yield of good-seed selection over original composite						Increase in acre yield of nearly disease-free check over good-seed selection					
						Total			Sound			Total			Sound		
				Total	Sound												
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Lot A Original composite	11	Cl. (5)	90.7	85.5	59.0												
Lot A Good-seed selection	11	Cl. (5)	95.0	94.1	72.0	8.6	10.1	113:1	13.0	22.0	>9999:1						
Nearly disease-free check	11	Cl. (10)	96.2	92.2	71.2							−1.9	−2.0	4:1	−0.8	−1.1	1:1
Lot A Original composite	10	Inf. (5)	92.5	78.2	57.5												
Lot A Good-seed selection	10	Inf. (5)	95.5	79.8	59.0	1.6	2.0	6:1	1.5	2.6	5:1						
Nearly disease-free check	10	Inf. (20)	98.1	83.2	64.6							3.4	4.3	713:1	5.6	9.5	1666:1
Lot A Original composite	28	Cl. (9)	88.9	80.0	49.7												
Lot A Good-seed selection	28	Cl. (9)	95.0	85.1	62.3	5.1	6.4	26:1	12.6	25.4	1666:1						
Nearly disease-free check	28	Cl. (18)	96.4	88.9	68.4							3.8	4.5	624:1	6.1	9.8	3332:1
Lot A Original composite	30	Inf. (9)	91.4	77.6	41.3												
Lot A Good-seed selection	30	Inf. (9)	93.9	85.6	56.4	8.0	10.3	587:1	15.1	36.6	587:1						
Nearly disease-free check	30	Inf. (18)	97.3	93.2	67.2							7.6	8.9	4999:1	10.8	19.1	>9999:1
Lot B Original composite	11	Cl. (5)	95.8	81.8	59.9												
Lot B Good-seed selection	11	Cl. (5)	96.2	78.0	58.5	−3.8	−4.6	8:1	−1.4	−2.3	2:1						
Nearly disease-free check	11	Cl. (10)	96.7	87.6	68.1							9.6	12.3	>9999:1	9.6	16.4	>9999:1
Lot B Original composite	10	Inf. (5)	95.7	75.9	51.4												
Lot B Good-seed selection	10	Inf. (5)	92.8	75.3	52.9	−0.6	−0.8	1:1	1.5	2.9	8:1						
Nearly disease-free check	10	Inf. (10)	97.8	83.1	64.1							7.8	10.4	158:1	11.2	21.2	>9999:1
Lot B Original composite	28	Cl. (9)	94.6	75.9	47.2												
Lot B Good-seed selection	28	Cl. (9)	97.3	82.2	53.7	6.3	8.3	999:1	6.5	13.8	59:1						
Nearly disease-free check	28	Cl. (18)	97.0	93.3	71.9							11.1	13.5	>9999:1	18.2	33.9	>9999:1

TABLE 29.—*Concluded*

Character of seed	Date of planting May	Soil infestation[1]	Field stand	Acre yield		Increase in acre yield of good-seed selection over original composite						Increase in acre yield of nearly disease-free check over good-seed selection					
				Total	Sound	Total			Sound			Total			Sound		
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Lot B Original composite	30	Inf. (9)	95.8	80.3	44.8												
Lot B Good-seed selection	30	Inf. (9)	97.3	78.6	50.8	−1.7	−2.1	4:1	6.0	13.4	35:1						
Nearly disease-free check	30	Inf. (18)	97.8	87.5	63.9							8.9	11.3	>9999:1	13.1	25.8	>9999:1
Lot C Original composite	11	Cl. (5)	91.7	78.5	57.6												
Lot C Good-seed selection	11	Cl. (5)	92.0	80.6	57.8	2.1	2.7	3:1	0.2	0.3	1:1						
Nearly disease-free check	11	Cl. (10)	95.9	84.7	67.1							4.1	5.1	13:1	9.3	16.1	555:1
Lot C Original composite	10	Inf. (5)	93.7	78.1	56.1												
Lot C Good-seed selection	10	Inf. (5)	93.8	78.8	60.2	0.7	0.9	1:1	4.1	7.3	3:1						
Nearly disease-free check	10	Inf. (10)	97.1	83.3	63.6							4.5	5.7	17:1	3.4	5.6	3:1
Lot C Original composite	28	Cl. (9)	93.5	86.2	58.7												
Lot C Good-seed selection	28	Cl. (9)	92.9	85.5	59.1	−0.7	−0.8	1:1	0.4	0.7	1:1						
Nearly disease-free check	28	Cl. (18)	98.2	96.3	74.5							10.8	12.6	>9999:1	15.4	26.1	>9999:1
Lot C Original composite	30	Inf. (9)	89.6	75.9	45.2												
Lot C Good-seed selection	30	Inf. (9)	94.9	77.2	53.3	1.3	1.7	1:1	8.1	17.9	16:1						
Nearly disease-free check	30	Inf. (18)	98.2	84.6	62.3							7.4	9.6	>9999:1	9.0	16.9	>9999:1

[1]Cl.=clean; Inf. infested; figures in parentheses represent number of replications.

TABLE 30.—SUMMARY OF TABLE 28, SHOWING THE VALUE OF SELECTING SEED ON THE BASIS OF PHYSICAL APPEARANCE

Character of seed	Soil	Number of plots	Mean acre yield		Increase in yield of sound corn of good-seed selections over original composites			Increase in yield of sound corn of nearly disease-free checks over good-seed selections		
			Total	Sound						
			bu.	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Original composites	Clean	42	81.1	54.1						
Good-seed composites	Clean	42	84.3	59.9	5.8	10.7	6714:1			
Nearly disease-free checks	Clean	84	91.1	69.8				9.9	16.5	>9999:1
Original composites	Infested	42	77.7	47.8						
Good-seed composites	Infested	42	79.6	55.1	7.3	15.3	>9999:1			
Nearly disease-free checks	Infested	84	86.4	64.3				9.2	16.7	>9999:1

TABLE 31.—YIELDS FROM LOT D AND FROM THE NEARLY DISEASE-FREE CHECK
Grown on brown silt loam of high fertility, Bloomington, 1921

Character of seed	Date of planting	Soil infestation	Field stand	Acre yield		Increase in acre yield of selected composite over original composite						Increase in acre yield of nearly disease-free check over selected composite					
				Total	Sound	Total			Sound			Total			Sound		
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Original composite	May 11	Cl. (5)	85.8	77.0	47.0												
Selected composite	May 11	Cl. (5)	91.9	76.0	44.1	−1.0	−1.3	1:1	−2.9	−6.2	2:1						
Nearly disease-free check	May 11	Cl. (10)	95.1	89.4	71.4							13.4	17.6	>9999:1	27.3	61.9	>9999:1
Original composite	May 10	Inf. (5)	87.2	73.4	44.6												
Selected composite	May 10	Inf. (5)	91.8	77.2	49.0	3.8	5.2	6:1	4.4	9.9	6:1						
Nearly disease-free check	May 10	Inf. (10)	98.9	87.2	68.2							10.0	13.0	>9999:1	19.2	39.2	>9999:1
Original composite	May 28	Cl. (9)	90.3	93.0	52.5												
Selected composite	May 28	Cl. (9)	94.0	92.7	56.0	−0.3	−0.3	1:1	3.5	6.7	4:1						
Nearly disease-free check	May 28	Cl. (18)	97.7	101.1	79.8							8.4	9.1	>9999:1	23.8	42.5	>9999:1
Original composite	May 30	Inf. (9)	88.2	74.7	35.5												
Selected composite	May 30	Inf. (9)	93.2	74.7	41.0	0.0	0.0		5.5	15.5	57:1						
Nearly disease-free check	May 30	Inf. (18)	97.5	81.4	59.2							6.7	9.0	>9999:1	18.2	44.4	>9999:1

Hopkins and carried on by Dr. L. H. Smith. A comparison of field data from the apparently good-seed selection, which had had no previous selection toward disease resistance, and from the nearly disease-free check, which had been selected a number of years toward disease resistance, is interesting and instructive at this point. In ten of the twelve comparisons (Table 29), the increases in yield of sound corn from the nearly disease-free check were significant, the odds ranging from 555 to 1 to greater than 9999 to 1. Corn grown from the check seed also gave significant increases both in total yield and yield of sound corn over that grown from the composite selected out of Lot D (Table 31). *Corn grown from the nearly disease-free check seed yielded at a higher rate in every instance than corn grown from apparently good-seed selections.*

SELECTION OF SEED EARS A FUNDAMENTAL OPERATION

Altho selection of seed ears on the basis of physical appearance has its limitations, it is a fundamental operation in any program for the developing of a strain of corn which will be more highly resistant to disease and to injury under unfavorable weather and soil conditions. The greatest improvement in resistance and productivity may be expected to accrue, however, not from physical selection of seed ears alone, but also from the continuous practice of plant selection and germinator selection, *always beginning with a strain which has possibilities for improvement.*

PART IV

A PROGRAM OF CORN IMPROVEMENT

SELECT A SUITABLE STRAIN WITH POSSIBILITIES FOR IMPROVEMENT

The choice of the foundation stock for a program of corn improvement is essentially a choice of variety. Varieties differ greatly not only in such characters as color of grain, time of maturity, and tendency to sucker, but also in the degree of adaptation to certain soils and climatic conditions and in the relative resistance to certain fungous diseases and insect pests. Even strains within a variety may show differences which, in some cases, are wider than those between so-called varieties.

A variety should be chosen that is well adapted to the local environmental conditions. It should mature well; it should be of a type that is not discriminated against commercially; and it should be sufficiently variable to show possibilities of improvement. The common varieties grown in the various sections of the country, in most cases, are well adapted to the conditions in those sections. Some strains, however, may have a low average production as compared with others, or may respond only feebly to a program of improvement. *Attention at the outset to the foundation stock to be used is essential to success.*

TWO METHODS OF IMPROVING CORN MAY BE USED

Two methods for corn improvement are suggested. The first emphasizes the importance of *selection* as a method of improvement. It is particularly adapted to the corn grower who desires a simple but effective method of improving his own crop. It also is adapted to the seed-corn producer who has built up a trade in seed corn because of his integrity and his ability to select good seed, handle it properly, and sell it at a reasonable price.

The second is called the *pure-line method*. It is believed to have a distinct place in a program of corn improvement because of its possibilities. By this method it would appear possible to produce hybrid strains that are highly resistant to a majority of the diseases affecting corn; that are adapted to the special conditions obtaining in different sections of the state, such as soil types, soil acidity, dry weather, lengths of season, and insect attack (the chinch-bug and European corn borer); and that are adapted to special uses, such as silage production, grain production, and manufacturing purposes (oil content). The pure-line method is fundamentally sound in theory, but the practical benefits from its use are, in the main, still to be realized.

THE SELECTION METHOD A PROFITABLE ONE AND CAN BE USED SUCCESSFULLY BY FARMERS

Much can be accomplished in the improvement of corn by paying particular attention to the plant in the field and to the ear in the seed-house and on the germinator. Selection at these three stages plays the most important part in the process of securing seed for the following crop. If this work were carefully and intelligently done year after year on every farm, the average corn yield for the state would be materially increased.

In corn improvement, special emphasis should be placed on the *quality* of grain produced. What is most desired is not high yield alone but *high yield of high quality corn.* Selection for disease-resistant corn according to the method outlined below results not only in improvement in total yield, but also in an increase in the proportion of sound, marketable grain.

SELECT WELL-MATURED EARS FROM UPRIGHT, VIGOROUS PLANTS

The parent plant (Fig. 38) should have an erect stalk, indicating a strong root system. It should be strong, vigorous, and healthy, free from smut, rust, and other diseases, with the leaves free from spottings, streaking, and purplings. The stalk and portions of the leaves should still be green. The husks should be dry and dead and they should be long enough to cover the tip of the ear completely. The ear should be borne at a height on the stalk convenient for husking, and on a strong shank of medium length. The angles which the ears form with the stalk should range from approximately 45° to 135°. Upright ears are likely to have large, coarse shanks, while ears hanging straight down are usually borne on small, weak, broken, or diseased shanks. Neither extreme is desirable.

PLANT SELECTION SHOULD BE MADE BEFORE KILLING FROST

In order to select well-matured ears, and at the same time give due attention to the parent plant with special reference to disease, *the field should be carefully inspected in the fall before a killing frost for the purpose of locating healthy, vigorous plants that are maturing normally.* If the field inspection is delayed until all the plants are dry and dead, it is difficult to distinguish those plants that matured normally. Ears from normally maturing plants will be found sounder and better matured, on the whole, than ears from diseased plants.

OFTEN POSSIBLE TO SELECT GOOD SEED AT HARVEST TIME

The mere fact that ears are selected in the field prior to harvest, with some attention to the parent plant, is, however, no assurance that they will make better seed ears than those selected at harvest time or

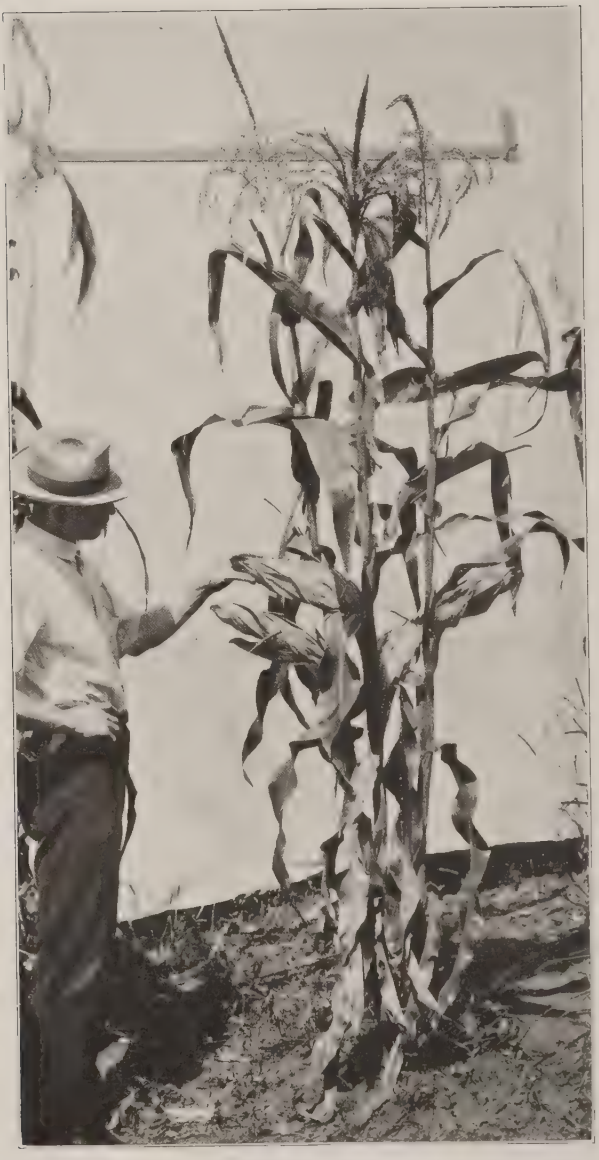

FIG. 38.—PLANT SELECTION, AN IMPORTANT OPERATION

Note the erect habit, the strong, vigorous, healthy appearance of the plants, and the manner in which the ears are borne, indicating healthy shanks. It has long been recognized that the parent plant, as well as the seed ear, should be considered in selecting seed corn.

even from the crib, for much depends on the care exercised in selecting the plant and in the handling of the ears afterward. Furthermore, it must be recognized that the majority of corn growers pick their seed corn at the time of harvest, and that they have obtained good results from this practice. As this method is so practical and inexpensive, it no doubt will continue to be widely used; it should not be con-

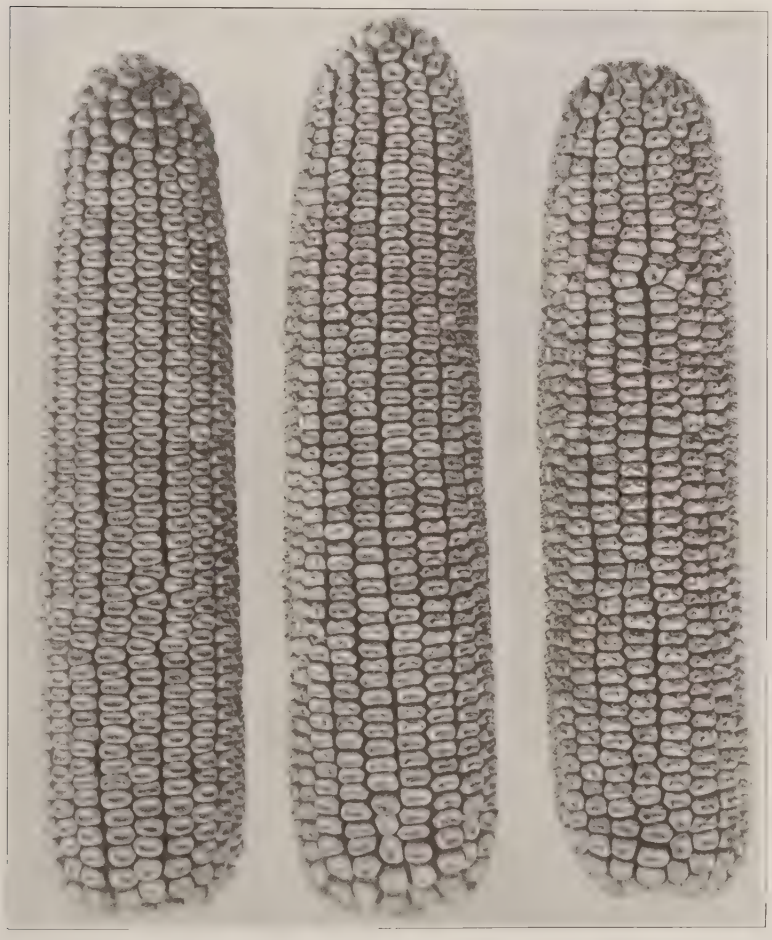

FIG. 39.—THREE DEGREES OF INDENTATION

The ear on the left represents the upper limit of the smooth class. The center ear represents the upper limit of the class variously called medium, intermediate, and mid-rough. Ears between these two in indentation would be classed as medium. The ear on the right illustrates the rough, starchy type. Avoid this type in ear selection.

demned so long as it results in the selection of normally matured ears that show good germination and relative freedom from disease. This method offers opportunity to choose from all the ears in the field, since all are actually seen and handled. Furthermore, many ears that would be taken for seed in the early fall would undoubtedly be rejected at the time of harvest because their seemingly good early appearance belied their appearance when fully matured. However, it is not advisable to select seed ears very late in the harvest period. Freezing temperatures, together with abundant moisture, especially if followed by warmer weather, will not only injure the germination of the seed but also will provide favorable conditions for infection and growth of fungi. At just what date in the fall harvest selection of seed ears should be discontinued must be decided individually by each corn grower in the light of conditions affecting his own crop.

PROPERLY STORE A SURPLUS OF SEED TO ALLOW FOR LATER CULLING

Four to five times as many ears should be picked for seed as will finally be used. This will allow the rejection of ears because of their appearance, or because of poor or weak germination, or the presence of disease. Much can be gained by having abundant opportunities to discard the less desirable ears in the final selection, and this is possible only in cases where large numbers of ears are on hand.

SELECT HEAVY, LUSTROUS, SMOOTH TO MODERATELY DENTED EARS, WITH SOUND SHANKS, WELL-COVERED TIPS AND BRIGHT, HORNY KERNELS

Nearly disease-free ears ordinarily can be distinguished from diseased ears by their general appearance, for the presence of disease interferes with the normal activities of the plant, and this interference is reflected in the color, luster, texture, and indentation of the kernels. A knowledge of this relationship is of distinct value to the corn breeder, for by it he can examine in a short time a large number of ears and quickly eliminate from further handling all but the very best.

Disease-free or nearly disease-free ears have thick, plump, bright, clean kernels with well-developed germs, intermediate to smooth indentation, and distinctly horny endosperm (Figs. 39 and 40). Such ears are sound and solid, have a bright, rather oily appearance, and give every evidence of complete and normal maturity. Shank attachments are white, bright, and free from any discoloration due to exposure or disease. All ears that do not measure up to these standards, or as many as the seed stock will allow, should be discarded, as they probably are more or less diseased.

In selecting corn for seed to continue the strain, *all* the points that are recognized as characteristics of good seed ears should be considered. Ears superior in one characteristic, such as shank attach-

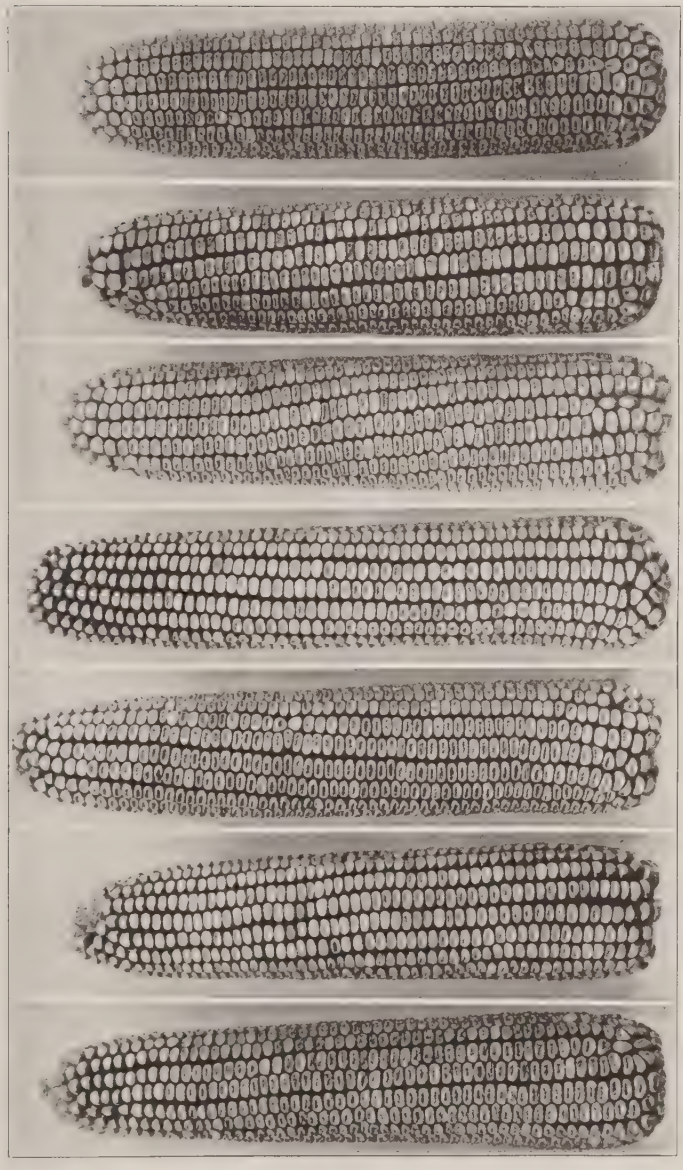

FIG. 40.—DESIRABLE SEED EARS

These ears show a considerable range in indentation, length, kernel type, and other characteristics. It is considered unwise to select too closely toward a particular type. Not only one, but *all* points indicating good maturity and good health, should be noted.

ments for example, may be inferior in kernel texture and luster. Such ears should be rejected in favor of ears which rank high in all three characteristics.

THE GERMINATOR TEST USEFUL IN DETECTING DISEASE AND SELECTING SEED OF SUPERIOR VIGOR

When circumstances permit, the ears that have been selected on the basis of their appearance should be tested on the germinator (preferably the lime-sawdust table germinator) in order to detect those ears that have high viability and seedling vigor and that are freest from the corn rot diseases.

There is considerable evidence that the germinator is especially useful also in detecting ears that are highly resistant to scutellum rot, resistance to which seems to be closely correlated with resistance to certain soil fungi and unfavorable environmental conditions. Thus the germination test may be very helpful in determining which are the *best* ears to use for seed.

The germination test, to be reliable, must be conducted under reasonably uniform conditions of temperature and moisture, and the results must be rightly interpreted. Many corn growers either do not have the proper facilities for conducting such a test, or are unable to read and interpret the results correctly. Emphasis must then be placed on plant and ear selection.

Since ears that have been carefully selected in the field and properly cared for can usually be depended on to germinate well and to show relatively little disease, lack of facilities for the germination test should not be considered a great handicap. Moreover, the limitations of the germination test should be clearly recognized. The use of the germinator will not always lead to improvement in all strains of corn, for some strains are incapable of further improvement, either because of defective heredity or because of their being in a relatively homogeneous condition. Other strains may be but slightly infected with the root rot organisms because of light infestation of the soil in which they were grown or because of a partial resistance to such infection resulting from conscious or unconscious selection for resistance over a period of years. *The primary purposes of the germinator are to show the presence or absence of disease and the vigor or lack of vigor of the seedlings.* If these purposes are not accomplished, then the germinator is of no aid in the improvement of corn.

THE PURE-LINE METHOD OFFERS GREAT PROMISE TO PROFESSIONAL PLANT BREEDERS

In the improvement of corn by the selection method just described, the ear was considered the basis of selection. Emphasis was placed on a careful study of the plant which produced the ear, i.e., the female

parent; the individual male parents could not be studied because they are unknown.

It is commonly accepted that the male parent is equally important with the female so far as the transmission of hereditary characters is concerned. All the kernels on an ordinary ear of corn have the same female parent but not the same male parent. Some kernels may be the result of self-fertilization, others the result of fertilization by pollen from neighboring plants in the same or in adjacent hills, and still others may have resulted from fertilization by pollen brought by the wind from more distant plants. The several male parents of the kernels on an ear of corn presumably differ greatly in their hereditary constitution. Hence, it is clear that the kernels may be quite different from each other even tho borne on the same cob and by the same female parent.

Corn breeders are coming to recognize that the pollen parent must not only be known but also controlled, that is, the male as well as the female parent must be *selected*. In order to do this, it is necessary to to control the pollen parent by artificial self-pollination.

As a result of continued self-fertilization, the vigor and yield decrease quite rapidly at first, then more and more slowly until finally a point is reached where no further deterioration is observed. The strain is then said to be pure, and it will continue to breed true thereafter for an indefinite period if no mixing occurs with other types.

A close study of the lines resulting from self-fertilization brings out the fact that some are good, others are poor, and still others are of indifferent value so far as capacity for production is concerned. Since all the plants in any one line are alike genetically, the corn breeder is confronted with the necessity of making a choice of the *best lines* rather than of the *best plants* as was the case in the selection method. Obviously, the best lines are those that possess characters favorable to production, such as resistance to disease and lodging, and that are themselves good producers of grain or of forage.

The next step toward improvement is to combine into one type the favorable factors which have been separated by self-fertilization. This is hybridization. A combination of two lines constitutes a single cross, four lines a double cross, and many lines a multiple cross. In the case of the single cross, best results are obtained by making the cross anew each year, while in the case of the double and multiple crosses it would appear possible to carry over the benefits of hybridization into the second, third, and subsequent hybrid generations by careful selection.

Briefly, then, the pure-line method involves first the purifying of strains by inbreeding and then the building up of a new and vigorous strain by outcrossing with other desirable pure lines.

PROBABLE USES OF THE TWO METHODS OF CORN IMPROVEMENT

The pure-line method is of incalculable value to the investigator. It provides him with a tool by means of which he can resolve the corn crop into its component elements and analyze them, saving what appears useful and discarding the rest. For example, he can isolate and recombine the genetic factors which affect root development and thus build up a type with a superior root system particularly adapted to drouth conditions.

Self-fertilization may be likened to the analytical method employed by the chemist. It is a breaking-down process according to which the investigator takes the corn crop as Nature has given it to him and determines of what it is made up. Then he takes the parts he wants and builds up, synthetically, the particular type desired, by hybridization. Hence, *analysis* and *synthesis* are the keynotes of this method.

For a considerable time probably, the method of *careful seed selection* will be largely used by the majority of seed producers and farmers in improving their corn. This must necessarily be the case, because of the length of time required to obtain tested lines for use in producing hybrid seed. While practical difficulties which have always been urged against the pure-line method are not believed to be insurmountable, the utilization of hybrid seed in corn production will be most efficient only when there is complete cooperation between the Experiment Station, the professional plant breeder, the seed producer, and the corn grower.

SUMMARY

On the basis of the data reported in this bulletin, as well as of observations made thruout Illinois for a period of years, the authors feel that where inferior and infected seed is used, losses to the corn crop from disease, including smut and rust, can very conservatively be placed at 20 percent.

An adequate understanding of the causes of the corn root, stalk, and ear rot diseases, and variations in susceptibility of different strains of corn to these diseases, can be obtained only by a consideration of all the influencing factors.

Planting of Diplodia-infected and Gibberella-infected seed always has resulted in a reduced stand, many blighted and weak plants, and a lowered vigor and vitality of those plants which survive.

Good seed corn of strong vitality and free from infection will grow under a wider range of temperature and moisture and can be planted with safety much earlier than infected seed or seed affected with scuttellum rot.

In general appearance, good seed ears are mid-sized, heavy in weight, bright in luster, moderately horny to horny in kernel com-

position, and moderately smooth to smooth in indentation. Shank attachments are bright or only slightly discolored, and in no case is there evidence of rotting of the tissues at the butt of the cob. Tips of the ears have been covered by the husks or only slightly exposed. Starchy seed, regardless of its germination record, is very likely to produce corn more or less susceptible to the attack of certain parasitic fungi and to injury from unfavorable weather or soil conditions.

An important consideration in corn production is disease resistance, a condition which, up to the present time, the authors have not found associated with starchy seed or infected horny seed, but rather generally associated with seed from apparently healthy plants that shows vigor and freedom from disease on the germinator and that is horny in composition.

Nearly disease-free seed of a susceptible strain or selection may yield even less than moderately diseased seed selected from apparently good plants of a highly resistant strain, thus suggesting the advantage of selecting seed in the field from standing plants and the value of the germination test in securing seed which will produce plants more highly resistant.

Some strains of corn are so susceptible to disease and so deficient in those qualities which make for high yield of sound corn that neither physical nor germinator selection can effect any improvement in either quality or quantity of the crop.

The relative degree of resistance and susceptibility possessed by different strains and selections of corn cannot always be determined accurately by plantings on one date in one locality involving only one set of environmental factors.

The greatest improvement in resistance and productivity may be expected to accrue, not from physical selection of seed ears alone, but also from the continuous practice of plant selection and germinator selection, always beginning with a strain which has possibilities for improvement.

Altho variations in disease resistance are greater in open-pollinated corn than in uniform inbred strains, yet there are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection. Complete resistance or immunity to a majority of the corn rot diseases seems possible only by the recombination of two or more highly resistant and reasonably productive inbred strains which nick together in a compatible way.

The data furnish strong arguments for the use of strains of corn resistant to disease and approved rotations in which there is a more liberal use of legumes. In fact, crop rotation appears to be as important a factor in determining yield of corn as are soil treatments.